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OLIVER EVANS AND HIS INVENTIONS.*

By COLEMAN SELLERS, JR.

[*Abstract of a Lecture delivered at the* FRANKLIN INSTITUTE, *November 20, 1885.*]

Of all the early American Mechanics, there is perhaps none who has left a more definite impress upon the industrial progress of our country than Oliver Evans, and there is none whose successes and failures are of more interest to the student of mechanical history. He is widely recognized as the inventor of improvements which completely revolutionized the processes of flour manufacture, and which remain in use to-day substantially as he left them.

* The writer desires to express his indebtedness for illustrations used in this lecture, to President Henry Morton, Stevens Institute of Technology, for lantern slide of the "Stevens Engine"; to Prof. Geo. F. Barker, of the University of Penna. for slides showing types of early locomotives; to Prof. Benjamin Sharp, also of the University, for transparency of Oliver Evans's portrait; and to Robert C. Davis, Esq., for information furnished and engraving loaned. C. S. Jr.

But it is not alone as an inventor of flour making machinery that he claims our attention, he is even more widely known for his earnest and successful efforts to introduce the high pressure steam engine, and by his enthusiastic advocacy of steam locomotion. Indeed, he has been styled the "Father of the High-Pressure Steam Engine," and it has been often said that he was the original projector of the locomotive and the inventor of the first practicable steamboat. These broad claims have generally been maintained by American writers and ignored by the English, who give much the same credit to Richard Trevethick, Oliver Evans's contemporary. It is, of course, difficult in any such case to clearly establish general claims to priority in the conception of ideas, but we can at least compare his work with that of other inventors of his time and form some judgment as to their relative merits. With this in view, it will be our task this evening to review briefly the life and labors of Oliver Evans, to acquire, if we can, a just appreciation of the true value of his work and his proper place among those geniuses to whom we owe the mechanical attainments of the present age; to learn, if we may, who and what he was, and what his environment; to learn the meagreness of his opportunities, the restrictions by which he was hampered, that we may the better understand the character and value of his inventions, and the measure of credit to which he was entitled.

Unfortunately, what is recorded of his life can be told in a few words, and is, indeed, little more than a history of his work. He was born near Newport, Del., in 1755, and died in New York City in 1819.

When he was born our country showed scarcely a trace of its present industrial development. The Atlantic seaboard was sparsely settled throughout its length, and a few adventurous pioneers were forming occasional settlements beyond the Alleghanies. Not only were there no railroads and no canals, but there were no tolerable highways of any kind except in the neighborhood of the larger towns. The goods required by the settler on the Ohio or Lake Erie were packed on horseback over the mountains, through Pennsylvania, by Lancaster and Chambersburg, or by the Southern route through Virginia, by Winchester, Hagerstown and Cumberland. It was not until 1789 that the first wagon load was sent over the Southern route to the

shores of the Ohio. These four-horse wagons would haul twenty hundred-weight from Hagerstown to Pittsburgh and back in about a month, and charge $3 a hundred-weight for hauling. Salt packed over the mountains sold in Pittsburgh for $8 a bushel as late as 1796, when salt from Western New York was introduced at half that cost.*

When Oliver Evans was born, there was just one steam engine on the American Continent; before he died, steam engines were in common use. During his life, good turnpikes were completed, canals projected and partly built, and steamboat navigation established on the great rivers. These were vast strides; but the crowning achievement, the railroad, which his prophetic eye discerned so clearly, he did not live to see an accomplished fact.

Evans was apprenticed at the age of fourteen to a wheelwright. He was a thoughtful, studious boy, who devoured eagerly the few books to which he had access, even by the light of a fire of shavings, when denied a candle by his parsimonious master. He says that in 1772, when only seventeen years old, he began to contrive some method of propelling land carriages by other means than animal power; and that he thought of a variety of devices, such as using the force of the wind and treadles worked by men; but as they were evidently inadequate, was about to give up the problem as unsolvable for want of a suitable source of power, when he heard that some neighboring blacksmith's boys had stopped up the touch-hole of a gun barrel, put in some water, rammed down a tight wad, and putting the breech into the smith's fire, the gun had discharged itself with a report like that of gun-powder. This immediately suggested to his fertile mind a new source of power, and he labored long to apply it, but without success, until there fell into his hands a book describing the old atmospheric steam engine of Newcomen, and he was at once struck with the fact that steam was only used to produce a vacuum, while to him it seemed clear that the elastic power of the steam if applied directly to moving the piston, would be far more efficient. He soon satisfied himself that he could make steam wagons, but could convince no one else of this possibility. At the age of twenty-two, he had completed a successful machine for making the wire teeth of wool cards, and

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* Bishop's *History of American Manufactures.*

then invented, but did not build, a machine for making and sticking the teeth in the leather backs. In 1780, he married the daughter of John Tomlinson, a Delaware farmer, and removed to Queen Anne County, Md., where he opened a store. Here he seems to have remained until 1782, when his two brothers, who were practical millers, persuaded him to join them in building a merchant flour mill in Newcastle County, Del. They started the mill September 5, 1785, and it required the constant attention of three men with "half the time of a boy." Evans was disgusted with the crude and laborious methods then in use and worked out a system of mechanical devices which could replace the labor of the attendants. In the old mill, the wheat or meal was handled at each stage of manufacture, and was carried from one point or one machine to another by manual labor. This he entirely revolutionized, and when he had applied his improvements, he found that the mill which formerly required more attention than three men could give was easily managed by one man; indeed, Evans wrote that once when a committee of millers came to see his new machinery, he took care to be at work in a neighboring hay field; they found the mill open and at work; and walking over it they saw that all the operations of milling were going on without the care of any attendant—cleaning, grinding and bolting all in progress without human intervention. This, Evans thought, would be convincing, but, they returned home and reported the whole contrivance "a set of rattle-traps unworthy the attention of men of common sense."

Having worked out his improved system and demonstrated its practical value, he set about putting it into general use. This he proposed to do by selling "rights" to millers; and he and his brothers canvassed Maryland, Pennsylvania, Delaware and Virginia without success, although they offered the right free to the first miller in any county who would put in the improvements. The greatest obstacle to his success was the obstinacy of the millers of the Brandywine, whose mills were the most celebrated in the country. They declined to put in his machinery on any reasonable terms, although he had shown them what it appears should have been a convincing proof of the value and utility of his improvements.

Oliver Evans was one of those discontented men who are not satisfied to do things in the time-honored, but perhaps clumsy way

in which they have always been done, and constantly sought opportunities to improve existing methods, and I fancy he generally found them. Certainly, the flour mill of the period badly needed mechanical assistance. Thomas Ellicott, who helped Evans in the preparation of his *Millwright and Millers' Guide*, in 1795, wrote that when he first began the business (about 1757): "Mills were at a low ebb in this country; neither burr-stones, nor rolling screens being used; and but few of the best merchant mills had a fan. Many carried the meal on their backs, and bolted it by hand even for merchant work; * * * it was counted extraordinary when they got their bolting to go by water; after fans by hand, and standing screens; then burr-stones, rolling screens, and superfine bolting cloths with a number of other improvements, some of the latest are the elevators, hopper-boys, etc., invented by Oliver Evans, late of Delaware, tho' now of Philadelphia. * * * By them the manufacture of grain into flour is carried on by water, with very little hand labor and much less waste, either in small or large business. And I do believe, that taking a large quantity of wheat together, that we can make two or three pounds more out of a bushel by the new than by the old way, although it be equally well ground; because it is so much more completely bolted, and with less waste. In the old way, the wheat is weighed and carried up one or two pair of stairs, and thrown into garners; the bags often having holes in, it is spilt and trampled under foot; several pounds being frequently lost in receiving a small quantity, and when it is taken from these garners, and carried to the rolling screens, some is again wasted, and as it is ground it is shovelled into tubs, a dust is raised, and some spilt and trampled on; it is then hoisted and spread, and tossed about with shovels, over a large floor, raked and turned to cool, and shovelled up again and put into the bolting hopper; all which occasions great labor, besides being spilt and trampled over the mill, which occasions a considerable waste. Besides these disadvantages, there are others in attending the bolting hoppers; being often let run empty, then filled too hard, so that they choke, which occasions the flour to be very unevenly bolted; sometimes too poor, and at other times too rich, which is a considerable loss; and when the flour is bolted, it is much finer at the head than the tail of the cloths; the fine goes through first, and has to be mixed by hand, with shovels or rakes;

and this labor is often neglected or only half done; by this means, part of the flour will be condemned for being too poor, and the rest be above the standard quality. The hoisting of the tail flour, mixing it with bran by hand and bolting it over, is attended with so much labor that it is seldom done to perfection."

It thus appears that the improvements in milling, which were originated by Evans, were chiefly in devices for handling the grain and its products during the processes of manufacture without the employment of manual labor. These devices were of various kinds, adapted to the nature of the service they were to perform, and in his publications Evans claimed five different ones, viz.: the *elevator*, for raising vertically; the *descender*, transferring down an incline; the *conveyor* and the *drill*, for moving horizontally, and the *hopper-boy*, whose function was to spread and cool the meal and feed it regularly into the bolting hopper. The *elevator*, perhaps the most important of these, was a modification of one of the oldest of machines, the "chain of pots," which had been used for raising water from time immemorial. As modified for raising grain, it was constructed of an endless flat band or strap, carried upon two drums or pulleys, and upon which, at regular intervals, a number of small troughs or buckets were so arranged that in passing under the lower pulley the buckets filled, and in passing over the upper one emptied themselves into a suitable box, from which a spout discharged the contents as required, the apparatus being kept in motion by power applied to the upper pulley. This machine has been vastly increased in size and capacity since Oliver Evans first put it to work in his little New Castle mill, and it is now applied to a multitude of uses that were never contemplated by him; but the device is essentially the same, and has proved itself to be one of the most useful of his inventions. The *descender* he himself described as "a broad, endless strap, of very thin, pliant leather, canvas, or flannel, etc., revolving over two pulleys, which turn on small pivots, in a case or trough, to prevent waste, one end of which is to be lower than the other. The grain or meal falls from the elevator on the upper strap, and by its gravity and fall sets the machine in motion and discharges the load over the lower pulley. There are two small buckets to bring up what may spill or fall off the strap and lodge in the bottom of the case." Although this machine would work by gravity even when the

descent was small, yet Evans recommended that power should be applied to it where practicable; and when driven in this way it became the prototype of the *belt conveyors* of the present day, which are generally used for the horizontal movement of grain in large quantities. Concave carrying rollers, or other devices, are now employed to compel the belt to form a trough which will hold a greater amount of grain than would stay on a flat belt. Evans also used for the same purpose the *drill*, which was simply an elevator laid horizontally, with wooden cleats, or, as he called them, "rakes," instead of buckets. These rakes scraped the grain along the bottom of the case or box in which they ran. The *conveyor* was simply a quick pitch screw of two or more threads, running in a trough or box into which it fitted closely. This screw, when used for grain, Evans made of a round wooden shaft, around which he nailed two or more sheet iron helices, or spirals, which, when the shaft was rotated, forced the grain along in the trough. When he desired to move flour or meal, he substituted for the sheet metal helix a number of radial arms, arranged spirally around an octagonal shaft.

The *hopper-boy* consisted of a slowly rotating vertical shaft, or spindle, the lower end of which passed through a horizontal beam, upon whose lower surface were arranged a number of inclined boards called "flights," whose function was to spread the meal and to gather it towards the bolting hopper. The horizontal arm also carried a "sweeper," or scraper, which pushed the meal into the hoppers, which were situated in the floor near the base of the vertical post. The meal was allowed to fall from the elevator at the extremity of the arm, which carried on each end an adjustable scraper, whose function was to drive the meal before it, trailing it in a circle, so as to discharge its load by the time it again reached the elevator. This circle of meal was collected by the "flights" and forced into the hoppers as described. The first flight, or that next to the scraper, could be swivelled so as to pile the meal in a ring to allow it more time to cool. As this ring increased in thickness, the arm rose on the spindle to suit. This was rendered easier by the fact that it was counterweighted over a pulley near the top of the spindle. The arm fitted loosely to the spindle, and was provided with an upper bearing of iron, by means of which it could be levelled, and it was driven by

means of a rope from a cross-beam near the top of the spindle. In order to deflect the grain delivered from an elevator in any particular bin, Evans used a pivoted wooden spout which could be rotated to suit his needs. All of these devices were efficient means of accomplishing the end in view, and were all of such a simple character that they could be readily constructed by the mill-wright with ordinary tools and materials.

At this time, the U. S. Patent Office had not been organized, and the several States exercised the privilege of granting exclusive rights to the use of inventions within their own boundaries. In 1786, Evans applied to the Legislature of Pennsylvania for a right to use his improvements in machinery for making flour, and also to use his steam wagons on the roads of the State. During this year, he explained his proposed engine to several people, and in particular his plan for propelling boats by paddle-wheels turned by steam engines. The following year, the legislature granted his flour mill patent, but made no allusion to the steam wagon claim; but on May 21st, the Legislature of Maryland granted both rights for fourteen years, on the ground that although it would doubtless do no good, yet it certainly could do no harm. A similar patent was subsequently granted (1789) by New Hampshire. About this time, the Ellicotts, well-known millers on the Patapsco, in Maryland, adopted Evans' improvements with great success, so that in making about 325 barrel of flour daily, they saved annually in wages $4,875, and increased the percentage of flour obtained from the wheat so as to reduce the cost of flour fifty cents per barrel, which amounted, Evans says, to a total saving of $32,500 yearly. In 1790, when the U. S. Patent Office was organized, Evans relinquished his State rights, and December 18, 1790, a U. S. patent was granted for his "method of manufacturing flour and meal." This is said to be one of the three patents granted that year. In 1794, he arranged with a Mr. Joseph Stacey Sampson, of Boston, to introduce and patent his steam engine improvements in England, and he furnished him with full drawings and specifications for this purpose. It is said that Mr. Sampson showed these papers to many English engineers, but that he died in England without having done anything to further Evans's interests.

Some time previous to 1790, Evans had removed to Philadelphia, and soon began the preparation of the *Millwright and Miller's*

Guide, which appeared in 1795. This book took three years to prepare, during which time he exhausted his capital, injured his eyes, and became gray. The first edition was of 2,000 copies, was published by subscription, and sold for $2 each to subscribers. He says that during this time his wife sold tow cloth of her own make to help feed their large family. In 1800, he had a mill about Third and Market Streets, and the next year was selling mill supplies at the southeast corner of Ninth and Market Streets.

Having tried in vain to induce some one to advance him the necessary capital to build an experimental traction engine, he began the work, in 1801, on his own responsibility, being moved thereto, he says, by sense of his obligations to the State of Maryland, which had granted him a patent when all others scouted at his visionary scheme. Before he had completed his engine, he concluded that as it differed from any of those then in use, it might be worth while to make some other application of it. He, therefore, changed his plans and started a small stationary engine, 6-inch cylinder, 18-inch stroke, which he had running in the winter of 1802, on Market Street. He set it to grinding and breaking plaster of Paris, then recently introduced as a fertilizer, and it broke and ground twelve tons in twenty-four hours; or when applied to sawing, with twelve saws, it cut up 100 feet of marble in twelve hours. This little engine and boiler cost him $3,700, including his own time, which he valued at $1,000. It took all his capital, and again, he tells us, he was impoverished. The success of this little engine lead to an order for one to drive a steamboat on the Mississippi. The boat was built 80 x 18 feet, at New Orleans, where Evans sent the engine. A freshet, however, left the boat stranded far from the river's edge, and while awaiting another rise to get her off again, the engine was removed and set to sawing lumber. This it did at the rate of 3,000 feet in twelve hours, which sold for $60 a 1,000, and in this time burned a cord and a-half of fuel. It is worthy of remark that this engine ran for a year without failure of any sort. An incendiary fire, attributed to the hand sawyers, whose business was injured by the engine, destroyed the mill, and the engine lay idle for nearly ten years, when it was again put to work, this time driving a cotton press. The boat and engine involved a loss of $15,000 to the enterprising owners.

In 1803, Evans started in business as a regular engine builder and he was probably the first in the United States to make a specialty of this work. The Philadelphia Board of Health ordered of Evans, in 1804, a steam dredging machine for cleansing the docks of the city. This machine he called the "*Oruktor Amphibolos*" or Amphibious Digger, and he described the craft and its performances as follows: "It consists of a heavy flat-bottomed boat, 30 feet long, and 12 feet broad, with a chain of buckets to bring up the mud, and hooks to clear away sticks, stones and other obstacles. These buckets are wrought by a small steam engine set in the boat, the cylinder of which is 5 inches diameter and the length of stroke 19 inches. This machine was constructed at my shop, one and one-half miles from the river Schuylkill, where she was launched. She sunk nineteen inches, displacing 551 cubic feet of water, which at 62·5 pounds, the weight of a cubic foot, gives the weight of the boat, 34,437 pounds, which divided by 213, the weight of a barrel of flour, gives the weight of 161 barrels of flour that boat and engine are equal to. Add to this the heavy pieces of timber and wheels used in transporting her, and the number of persons generally in her, will make the whole burden equal to at least 200 barrels of flour. Yet this small engine moved so great a burden with a gentle motion up Market Street and around the Centre Square; and we concluded from the experiment that the engine was able to rise any ascent allowed by law on turnpike roads, which is not more than four degrees. Before launching, July, 1805, this machine was run during several days around Centre Square, and the daily papers of that time contain an advertisement by Evans, in which he invited those interested to visit the square and inspect the *Oruktor Amphibolos;* he also mentioned that twenty-five cents a piece would be collected from those of the spectators who felt disposed to contribute it, and said that one-half of the sum thus realized he proposed to retain himself, and promised to expend it in the prosecution of other useful inventions; the remaining half of this money he proposed to divide among his workmen who, he further said, at their own expense, provided the wheels and axles upon which the scow was mounted, those first made having failed on account of their inability to support the great weight put upon them. Finally the scow was launched at Market Street Wharf, the engine having been connected with the paddle

wheel, she steamed down the Schuylkill and up the Delaware to her dock."

Having satisfied himself that he could build a traction engine, he made September 26, 1804, a statement to the managers of the Philadelphia and Lancaster Turnpike Company, in which he set forth the comparative expense of hauling by steam and horse-power, and showed conclusively, in his estimation, that by adopting his proposed engines they could nearly treble the net profits they made with the Conestoga wagons. He proposed that this traction engine should carry 100 barrels of flour, travel three miles per hour on a level road, and one mile an hour up and down hills, and it was to make the trip to Columbia in forty-eight hours; while to carry the same load in the usual way took five wagons, with five horses each, seventy-three hours. No attention seems to have been paid this document, and in December of the same year we find him petitioning Congress to extend the term of his flour mill patents. The bill passed safely to a third reading when an unexpected opposition arose which caused its defeat. While anticipating the favorable action of Congress, Evans advertised a new book to be entitled *The Young Engineer's Guide*, upon which he proposed to expend $3,000 and produce a very exhaustive and valuable work. Completely disheartened by the failure of his bill, and deprived of the additional royalties he felt sure of getting, he was obliged to issue a much smaller book than he had intended, and to omit many of the illustrations which he had promised. This abridged volume, he called *The Abortion of the Young Engineer's Guide*.

Evans expected great things from the extension of his patents, for although his royalties had been very low, yet comparatively few millers adopted his inventions, while the first patents were in force. After their expiration, the millers hastened to avail themselves of the advantages offered by his improvements and when, in 1808, Congress finally passed a bill continuing his patent rights for twenty-two years and protecting him for the interval between the expiration of his first patents and the date of the regrant, Evans felt that better days had at last dawned upon him. He put up prices from $30 for one pair of four and one-half feet stones to $300, and from $200 for five pairs of seven-feet stones to $3,675; but no great success appears to have attended this move, for

whereas some mill-owners, Thos. Jefferson, for instance, paid the license; most of them refused and were only compelled by process of law, which involved the inventor in a series of expensive and troublesome litigations. It is probable, however, that from this time his circumstances were somewhat more comfortable.

In 1803, Mr. B. H. Latrobe, in his report to the American Philosophical Society, describes five or six engines then at work in the United States, and among others mentions "a small engine erected by Mr. Oliver Evans." This was doubtless his first engine, that which he started the year previous to Mr. Latrobe's report.

In 1807, he established the Mars Works, at the corner of Ninth and Vine Streets, Philadelphia, and announced himself as an iron founder and steam engineer. This business he carried on until his death. In 1810, he associated with him his sons-in-law, James I. Rush, and David P. Muhlenberg, and shortly afterwards they purchased the lot at the corner of Sixteenth and Buttonwood Streets, which is now occupied by a portion of Mr. James Moore's Bush Hill Iron Works.

In 1812, he mentions ten of his engines as being then in use, and four years later he claims fifty. In 1817, he received an order for an engine and boilers for the Fairmount Water Works. This engine had a 20-inch cylinder, 5-foot stroke and was started in December of that year. It was supplied by four cast-iron boilers, 30-inch diameter, 24 feet long, carrying steam at pressures ranging from 194 to 220 pounds per square inch. Its product was 3,072,606 ale gallons, pumped 102 feet high in twenty-four hours, at an expenditure of 1,660 cubic feet of wood. It does not appear to have been an entire success, and the boilers burst on three different occasions.

Evans seized every opportunity to press his claims for the high-pressure engine. He set forth his views at some length in *The Abortion of the Young Engineers Guide*, in 1805, describing his engine and its application to various duties, gave rules for pressure and point of "cut-off," and recommended a cylindrical boiler, 3 feet diameter, with a maximum length of from 20 to 30 feet. In this work, he republished some of his previous papers and also the acrimonious correspondence carried on in the *Repository* between himself and Col. Stevens, of Hoboken, N. J., in which he accused the latter of appropriating his ideas. In this

work, Evans also described his projected volcanic steam engine, in which the products of combustion were to be passed into the water to assist in vaporizing it; and he also set forth a scheme of mechanical refrigeration.

In the *Emporium of the Arts and Sciences*, Vol. 2, published in Carlisle, Pa., 1812, we find quite an extended account of the state of the steam engine at that period, and the feeling against the use of high-pressure steam is well illustrated by an account of the explosion of one of Trevethick's boilers with fatal effect. This fear of the power of high-pressure steam dated from the time of Watt, who thought Richard Trevethick ought to have been hanged for using it, and was a potent factor in the opposition which Evans encountered in his efforts to introduce his engine. In the *Emporium*, he gave an account of his "Columbian Condensing High-Pressure Steam Engine," somewhat modified from that shown in his earlier publications; he also described the progress of his invention and reiterated his offer to make a steam carriage that would "run on good level railways," at the rate of fifteen miles an hour; and repeated his oft-quoted prophecy as to the future of the railroad *

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* "The time will come when people will travel in stages moved by steam engines from one city to another almost as fast as birds fly—fifteen to twenty miles an hour. Passing through the air with such velocity—changing the scenes in such rapid succession—will be the most exhilarating, delightful exercise. A carriage will set out from Washington in the morning, and the passengers will breakfast at Baltimore, dine at Philadelphia, and sup at New York the same day.

"To accomplish this, two sets of railways will be laid so nearly level as not in any place to deviate more than two degrees from a horizontal line, made of wood or iron, on smooth paths of broken stone or gravel, with a rail to guide the carriages so that they may pass each other in different directions and travel by night as well as by day; and the passengers will sleep in these stages as comfortably as they do now in steam stage-boats. A steam engine that will consume from one-quarter to one-half a cord of wood will drive a carriage 180 miles in twelve hours, with twenty or thirty passengers, and will not consume six gallons of water. The carriages will not be overloaded with fuel or water. * * * And it shall come to pass that the memory of those sordid and wicked wretches who oppose such improvements will be execrated by every good man, as they ought to be now.

"Posterity will not be able to discover why the Legislature or Congress did not grant the inventor such protection as might have enabled him to put in operation these great improvements sooner—he having asked neither money nor a monopoly of any existing thing."—*Extract from Address to the People of the United States.*

Evans again appeared in print in 1815, when he published an address to the people of the United States, in which he offered the use of his patented improvements in steam engines for propelling boats or land carriages upon liberal terms to any who would form companies for the purposes of using them. In 1816, he published "An Exposition of Part of the Patent Law by a Native-born Citizen of the United States, to which is added Reflections on the Patent Laws." During his struggle to secure from Congress an extension of his patent rights, Evans issued a pamphlet entitled "Oliver Evans to His Counsel who are Engaged in the Defense of His Patent Rights for the Improvements He has Invented, Containing a Short Account of Two out of Eighty of His Inventions, their Use and Progress in Despite of All Opposition and Difficulty, and Two of his Patents with Explanations."

The "drawings and specifications" of the eighty inventions mentioned in this formidable title were ruthlessly committed to the flames in the presence of his assembled family, while he was suffering under the mortification caused by the defeat of his application to Congress; and there is every reason to believe that he ever afterwards sincerely regretted this foolish act.

In April, 1819, Evans was visiting in New York City, when he received the distressing information that his Philadelphia shop had been destroyed by an incendiary fire. This news appears to have brought on a fatal attack of apoplexy, and he died on the twenty-first of the month. Thus ended in a new and bitter disappointment the life of one whose existence seems to have been one long struggle against the incredulity and prejudice of those whom he sought to benefit. He lacked the capital to carry out his cherished schemes and keenly felt the apathy which prevented the accomplishment of his great purposes.

His life, though full of disappointments, was not without its compensations; the success of his steam engine was itself a triumph and a vindication, and the universal adoption of his mill improvements afforded him more or less remuneration, and increased his business as a millwright and engineer. In regard to these improvements, there can scarcely be two opinions, his own testimony is amply supported by contemporary evidence that is unassailable. His theories of physics, especially of thermo-dynamics were doubtless, many of them faulty enough as might be expected from one whose

scientific knowledge was so scanty, and whose books were so few; but his mechanical ideas were seldom at fault, and his constructions were the best that his opportunities afforded. His application of the ancient chain of pots to lifting solids was a most felicitous conception, and has found its way into many other branches of industry not contemplated by him.

His system of handling grain, modified in detail only, in principle the same as he left it, is now used in all our flour mills, in all of the grain elevators which mark the railroad stations in our great Western wheat country, and the vast granaries of the railroad termini, with their capacity for holding millions of bushels: this system handles every grain of wheat from the time it leaves the wagon of the Western farmer, until it is packed, as flour in some gigantic Minneapolis mill, or stored in the hold of the trans-Atlantic steamer.

With regard to Oliver Evans' connection with the steam engine, this much we can safely say, that he early conceived the idea of using steam of high pressure, that he lost no opportunity to bring his views to the attention of those whom he thought could assist him in the realization of his hopes; that he built a successful steam engine in 1802; drove a heavy wagon by steam in 1805, and propelled a boat by steam-driven paddle-wheels the same year. That the type of engines he designed (small diameter of cylinder and long stroke) continued for many years the distinctive American engine. We see that he helped to overcome, by his personal exertions, the universal fear of high pressure steam, and introduced a type of engines which, by their lightness and cheapness, were fitted for the needs of a new settlement. But that he was the first man to conceive of the idea of using high pressure steam is scarcely probable; that he originated the locomotive is very doubtful. A Frenchman named Cugnot built a model high pressure traction engine in 1769, which ran for a time about the streets of Paris, until it upset, and was, with its inventor, promptly cast into prison. The next year he made a second, which is still in existence in Paris, and failed chiefly because its boiler was too small. In 1784, Murdock made a model high-pressure engine, and Watt in his patent put forth the idea of a steam carriage for common roads. This was two years before Evans applied for his patent in Pennsylvania. In 1800, Trevethick made an engine with beam, cylinder 19 inches

diameter, 5 feet stroke, and, in 1802, he took out his patents. There are certainly many points of similarity between the engines of Trevethick and Evans, but I do not think it is proved that the former copied the drawings of the latter, or even appropriated his ideas. It is much more likely that the two inventors, having the same goal before them, endeavored to arrive at it by the same means, or, as Oliver Evans says of another, "it frequently happens that two persons, reasoning right on a mechanical subject, think alike and invent the same thing without any communication with each other."

We can afford to grant a measure of merit to Evans's contemporaries without injuring his memory. He accomplished enough to establish his reputation upon a firm basis. What he might have done with better facilities and ample capital we can scarcely conjecture. My own opinion is that he underestimated the difficulty of building such a traction engine as he conceived possible, and from the fact that such engines are only now coming into anything like common use in this country, I fear that had he been permitted to carry out his ideas, the result would have fallen far short of his cherished expectations. We cannot but admire the pluck and determination with which he endeavored to develop his inventions, the courage with which he expressed his convictions. In the words of the late Mr. Joseph Harrison, Jr.: "*He*, with no misgivings as to the future, and with no dimmed vision, saw with prophetic eyes all that we now see. To him the present picture in all its grandeur and importance, glowed in broad sunlight."

And as was said by another: "Wherever the steam mill resounds with the hum of industry, whether grinding flour on * * the Schuylkill, or cutting logs in Oregon, there you find a monument to the memory of Oliver Evans."

Magnesium for Illumination.—M. Graetzel has succeeded in producing pure magnesium by an electrolytic method, at a price much below the rates at which it has hitherto been sold. Serious thoughts have thus been awakened of employing it for ordinary lighting purposes. The Bremen factory of aluminium and magnesium, which uses Graetzel's processes, has just organized an exhibition for magnesium lamps with clock-work movements. Two prizes of $125 and of $50, will be awarded to the makers of the lamps, which shall be adjudged the best and the most practical.—*Ann. Industr., Cosmos, Aug. 24, 1885.*

THE APPLICATIONS OF ELECTRICITY TO THE DEVELOPMENT OF MARKSMANSHIP.

BY O. E. MICHAELIS, Captain of Ordnance, U. S. A.

[*A Lecture delivered before the* FRANKLIN INSTITUTE, *March 15, 1886.*]

Recent events with which you are all familiar appear to emphasize the correctness of the general belief that a soldier should be a man of action rather than a man of words. The question must then naturally suggest itself to you, why I have the temerity to appear before you this evening as a reader or talker. I gained so much information through my official connection with the Electrical Exhibition, and was treated with such extreme kindness and courtesy by its managers, that I esteem it a great privilege to be afforded an opportunity of showing my appreciation and gratitude by attempting to impart, as well as I may be able, such special knowledge as I am flatteringly supposed to possess. The general subject of the application of electricity to warfare has already been exhaustively treated by my able colleague, Lieutenant Fiske, of the Navy, and my distinguished friend, Professor Abbé, has a prescriptive right to the "Signal Service Electrical Methods," hence my subject had to be special, and I determined to attempt to investigate the influence of electricity in the development of the science of gunnery, by briefly sketching the origin and expansion of our knowledge of the flight of projectiles, and by showing the astonishing facility and accuracy attained in this necessary investigation by the introduction and use of electrical apparatus.

Probably many of you who are present saw a year or so ago that unique exhibition called the "Wild West," and were astonished by the marvellous shooting of "Buffalo Bill." You may possibly have as souvenirs half-dollars hit by him in mid-air, at the distance of about thirty feet. In the execution of this apparently wonderful shooting, he used a Winchester repeating rifle, with a charge of thirty grains of powder, and a bullet weighing 200 grains. His mark, a silver half-dollar, was 1·2 inches in diameter. Now please keep in mind, Buffalo Bill's distance, thirty feet, and his mark, 1·2 inches in diameter. Marksmen, both in the National Guard and in the Army have made ten consecutive bull's-eyes at

1,000 yards, using charges of 100 grains or over, and bullets weighing 500 grains.

Let us compare this performance with Buffalo Bill's striking exhibition. The bull's-eye at 1,000 yards is three feet in diameter;

FIG. 1.—Silver Half-dollar.

1,000 yd. "bull's-eye," as seen at 10 yds.

this reduced to ten yards would be $\frac{36}{100}$ of an inch, $\frac{3}{10}$ths the size of the silver half-dollar. It is true the silver half-dollar was a moving object, but when you consider its low velocity and its comparatively large size, the feat is not so difficult as the clean score of the military shot. The latter, too, has to contend with both the moral and physical effect of severe recoil, with wind effect or deviation, with the diverting influence of the projectile's rotation or drift, and, in fact, with all cumulative atmospheric influences. If you will remember that the minutest error at the firing point produces most exaggerated effects at the distance of the target, 1,000 yards, you will agree that making bull's-eyes at this distance must be the convergent result of correct judgment, dauntless nerve and abstruse science.

The first two are personal qualities, inborn or acquired; the latter is exhibited in the development of the arm and projectile, and in the manufacture of the propelling agent, *gunpowder.*

It would be exceedingly interesting to investigate the moral causes that tend to make individuals good marksmen. We would find ourselves involved in an absorbing ethnological study, and would soon be convinced that the same race-qualities that brought about religious freedom, the writ of *habeas corpus*, and trial by jury, are also necessary concomitant elements in the growth of national good-marksmanship. But for the purposes of this paper, we must assume that the man who points the gun has all the requisite attributes of mind and body that characterize the good shot. I may say, however, that the general interest and

great improvement in target practice in this country during the past decade is, in great measure, due to the establishment of Creedmoor, to the energy and enthusiasm of General Geo. F. Wingate, and, so far as the army is concerned, to the excellent manuals of Laidley and Blunt. It would also be instructive to study the evolution of the weapon from the earliest match-lock, through wheel-lock, flint-lock, percussion-lock, to the present accurate long range rifle; from the Ho-pao, the Chinese fire-gun, to the gigantic sixteen-inch Krupp breech-loader, dwelling, in passing, upon the remarkable prophecy of Benjamin Robins, published in 1747, and fulfilled in the brilliant Italian campaign of 1859.

"I shall, therefore, close this paper with predicting that whatever state shall thoroughly comprehend the nature and advantages of rifled barrel pieces, and, having facilitated and compleated their construction, shall introduce into their armies their general use with a dexterity in the management of them; they will by this means acquire a superiority which will almost equal anything that has been done at any time by the particular excellence of any one kind of arms, and will perhaps fall but little short of the wonderful effects which histories relate to have been formerly produced by the first inventors of firearms."

But, again, for our purpose this evening, we must take the results of this investigation for granted, and assume that our ethnologically developed marksman is armed with the scientifically evolved weapon.

There remains, then, the consideration of the propelling agent still, up to this late period of the nineteenth century—*gunpowder*.

Accurate results are produced by controllable causes.

Accurate shooting is within limits a direct function of the man, the gun and the powder The man and the gun being assumed, it follows that to assure uniform results we must have uniform powder.

While on duty in the West, travelling in Montana, Dakota, etc., I have several times met fine shots without any scientific knowledge, who, when I asked them what allowances they made for disturbing influences, replied that they aimed "about thar," and in so doing they hit. This reply is their unconscious confirmation of what I have just stated, that to assure uniform results we must have uniform powder; for experience has given them

the personal equation of man, gun and ammunition, and it is the constancy of these components that produces the accurate result.

And a brief investigation of one of the modern means of controlling this essential uniformity of the product of our powder mills is the gist of this evening's paper, and enables me to show you that this branch of scientific inquiry was not improperly accorded a place in the great International Electrical Exhibition of the FRANKLIN INSTITUTE.

Gunpowder, as is well known, is a mechanical mixture or incorporation of nitre, sulphur and charcoal. To produce the best results, these substances must be refined, pure. Special care, the reward of long experience (our own most famous makers have been for generations in the business), is required in the admixture of these ingredients. Certain volumetric and gravimetric densities, specific weights and granulations, are best adapted for given required effects, and I wish it were within the scope of this evening's paper to tell you how these are observed and controlled. The tendency of modern progress has been to leave the manufacturer unhampered as to quality of ingredients or method of treatment, and, instead, to demand of him a powder that shall yield a certain *definite* result. This result is measured by the expressed *power* of his product, determined by its effect upon the arm and the projectile. The former is called pressure, the latter velocity. In reality, these are not distinct manifestations of power, for did we know the velocity of the projectile at every point within the barrel, the effective pressure at these points could be deduced. The magic mixture, simulating thunder and lightning in its ignition, which drove Roger Bacon from Oxford, the detonating compound with which Berthold Schwartz armed European feudal chivalry to its own destruction, was a very different thing from the mighty, controllable agent produced at present upon the banks of our historic Brandywine.

This great development has been brought about by the methodical observance of expressed effects, and has culminated to-day in our ability to control these effects.

As has been said of one of the greatest of Philadelphians, we have chained the lightning, and to tell you briefly how this has been brought about is my main object to-night.

Benjamin Robins, Fellow of the Royal Society, is the founder

of the modern scientific method of investigating the force of fired powder. His work, "New Principles of Gunnery; Containing the Determination of the Force of Gun Powder, and an Investigation of the Difference in the Resisting Power of the Air to Swift and Slow Motions," was first printed in 1742.

For this, and for subsequent papers on the same subject, read before the Royal Society, in 1746 and 1747, he received its gold medal. In presenting the medal, the President made an address, from which I quote, simply to show the contemporaneous opinion of Robins's work.

"It is from these experiments, and from those others which Mr. Robins is still preparing to exhibit that we may expect to see compleated the whole, and the true theory of projectiles.

"What Galileo and Torricelli,who first demonstrated the motions of these bodies *in vacuo*, knew to be still wanting in their theories, will hereby be supplied, and these particulars will at last become known, which they wished that future observers would make diligent and careful experiment about. The great Sir Isaac Newton, who did so much honour when living, not only to this Society and to this Chair; not only to this country and to the age he lived in, but to the world in general, and to human nature itself; this great man, I say, in his admirable 'Principia,' investigated the laws of the resistances made to bodies in motion, during their passage through the air and other fluids, and those upon different theories, and upon different suppositions.

"He also made experiments upon the resistance given to funipendulous bodies in their oscillations, and to others in their fall, which he caused to be dropped for that purpose from the highest part of the cupola of St. Paul's Church; but he never had the opportunity of making trials upon those much greater resistances, that shells and bullets are impeded by, in those immense velocities with which they are thrown from military engines. And hence it has come to pass that succeeding writers, even those of the first class, and who are the most justly distinguished by their great knowledge and abilities, not sufficiently attending to the true theory of these motions, have been of opinion that in large shot of metal, whose weight many thousand times surpasses that of air, and whose force is very great in proportion to the surface wherewith they press thereon, this opposition is scarce discernable, and

as such may, in all computations concerning the ranges of great and weighty bombs, be very safely neglected. This is one of those principles which the learned gentleman, who favored us with these experiments, very particularly proposed to examine, and that both theoretically and practically."

A recent author thus speaks of this profound experimenter:

"Benjamin Robins, the eminent scientific English artillerist, whose researches and experiments, conducted with such remarkable ability, skill and perseverance, effected so much and led the way for the introduction of the more recent improvements in gunnery, died in the year 1751. His able works continue to be regarded as possessing the highest authority."

I have already given you a glimpse of his prescience by quoting his prediction regarding rifled arms. Almost every great modern improvement in artillery science is foreshadowed in his writings.

Almost to the middle of the sixteenth century, projectiles were supposed to move in right lines. Tartaglia, in 1537, first attempted to reason concerning the form of a projectile's path, and came to the conclusion that the trajectory was made of three parts, a straight line, an arc of a circle, and another straight line. One hundred years later, Galileo printed his dialogues on motion, in which he pointed out the general laws of motion, and first described the action and effect of gravity upon falling bodies. From these investigations he determined that the trajectory of a projectile *in vacuo* was a parabola. Our personal observation and experience would naturally lead us to assume our atmosphere as a very type of non-resisting fluids, and hence we are not qualified to estimate the enormous force it opposes to bodies moving through it with great velocity.

Galileo experimented with slowly moving bodies, to which the air offered but slight resistance, and while aware of its existence, he considered its effect insignificant.

The crude ideas that artillerists had relative to the path of a fired projectile were abandoned, it was assumed that all projectiles moved in parabolic curves, and that the resistance of the air on account of the enormous relative weight of the "mobile" could have no appreciable effect upon its flight. These views were maintained in England, by Anderson, "Genuine Use and Effects of the Gunne," 1674, in France, by Blondel, "Art de jetter les Bombes,"

1683, and also by Dr. Halley, in the "Philosophical Transactions" of 1686. Notwithstanding Newton's warning, given in the "Principia," in 1687, confirmed by Huygens in 1690, notwithstanding Ressous's utter skepticism announced before the Academy in 1716, these erroneous views were held almost universally until overthrown by Robins's experiments.

This scientist saw that he must show an agreement between theoretical and practical results in order to establish his theories as facts, and to accomplish this, he invented, to use his own words, "a new method of finding the real velocity of bullets of all kinds," and this apparatus, described in 1742, was the first practical velocimeter. Attempts had been made before this time to determine the velocity of projectiles; the time of flight over a given space had been observed, and the velocity deduced therefrom, of course with an accidental error of anywhere from 200 to 600 feet per second.

Again the range at a given elevation had been measured and the velocity calculated on the parabolic theory, fallacious in result, as we now know, on account of the resistance of the air.

Powder was "proved" by means of the *eprouvette*, a method in vogue until comparatively very recent years. Colonel Louis De Tousard, an educated French artillery officer, who served as inspector of our artillery, and to whom I shall again refer, gives the following description of this method in his "American Artillerists' Companion," begun in compliance with the wishes of Washington, in the year 1795.

"In the proof of gunpowder, use is made of a brass mortar, called *eprouvette*, cast upon a bed of the same metal. The *eprouvette* points under an angle of 45° when the bed is horizontal. Its calibre is 7·52 inches, and projects a solid globe of copper weighing sixty pounds. Formerly three ounces of new powder projected this globe 180 yards; remanufactured powder 160. At this time 3 ounces 5⅜ grains of new powder must carry this globe 216 yards. The same quantity of remanufactured powder must carry the globe 185 yards. The *eprouvette* is the most exact firearm we have, because its ball has little windage, and because it consequently receives a less lateral direction, which may turn it from the direct course; besides the inflammation acts upon it with all the force of which it is susceptible, since very little of the elastic fluid escapes round the ball."

Before describing Robins's method of determining the velocity, I will anticipate for a moment, and tell you of the principal attempts made on the Continent in continuation, possibly in evasion, of his experiments. In 1767, Mattei, an Italian instrument maker contrived a machine for determining velocities. It consisted of a vertical paper cylinder mounted in a wooden frame, and made to rotate by means of a cord and weight. A uniform, known speed having been attained by it, the projectile was fired through it, perpendicularly to the axis, and the position of the resulting two holes in the surface gave the arc through which the cylinder had rotated during the passage of the bullet. It was assumed that the ball traversed the cylinder with a uniform velocity, and it is apparent that the precision of the results is a function of the diameter of the cylinder, and of the rapidity and uniformity of its revolution.

The probabilities are that this machine could not measure less than the one-thirtieth of a second, during which period a modern projectile covers from forty to seventy feet. That "there is nothing new under the sun" is well illustrated by these early devices for measuring initial velocity. Mattei's machine is the prototype of a large class of modern instruments for noting minute time intervals between consecutive events. I refer to the use of a uniformly rotating cylinder. A notable example is the astronomical chronograph. For the very small intervals required to be observed in ballistic investigations, this principal is not reliable, for we cannot depend upon the fractional uniformity of rotation of the cylinder. The ingenious, simple, and accurate measure in which this objection has been overcome will be seen later.

In 1804, Colonel Grobert, of the French army, introduced an important modification of Mattei's device. The cylinder was reduced to its heads, and the axis was made horizontal. That is, two discs of card-board about 6½ feet in diameter, were mounted on each end of a horizontal shaft about 13 feet long. These discs were divided into 360° by radii lying in the same meridian plane, and were similarly graduated. An endless chain in combination with a windlass and fly wheel produced rotation, which was timed after having become apparently uniform. The piece was fired parallel to the axis through both discs. You can readily see that here, as in Mattei's machine, the duration of the trajectory between the discs was given by the angle of revolution.

This apparatus depended for its precision upon the same, then almost impossible, conditions that Mattei's required. Even this modified cylinder apparatus has apparently been revived in one of the latest English chronoscopes, which is thus described in part: "The mechanical arrangement of the instrument consists of a series of thin metal discs each thirty-six inches in circumference, fixed at intervals upon a horizontal shaft, which is driven at high speed by a heavy descending weight."

The next important step was taken by another French officer, Colonel Dabooz, who, in 1818, contrived a gravity apparatus for measuring initial velocities. At fifty yards from the gun, he placed a fixed screen, immediately in front and above this, he suspended another screen, hung by a cord, which passed over pulleys, and was stretched by a balancing weight in front of the

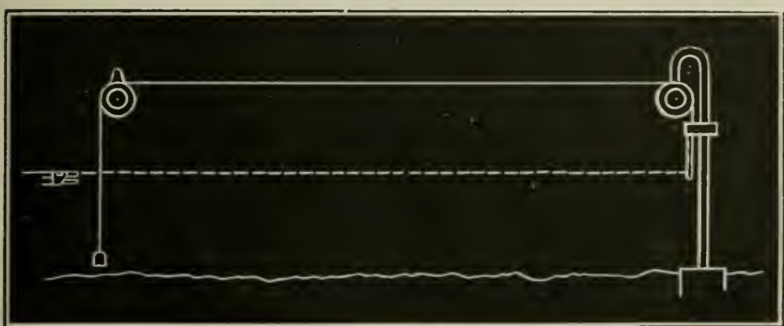

FIG. 1½.—Dabooz's Method of Determining Velocities.

muzzle of the gun. The projectile cut the cord, the movable screen fell, and both it and the fixed screen were perforated at the same instant. The relative distance between the holes gave the duration. Of course, you see that the main error here is due to the fact that the movable screen does not fall at the instant the restraining cord is severed. I will show you presently how this very correct principle has been applied in late years, and how very elegantly and completely this instrumental and accidental error has been eliminated.

Many other variations of these devices for measuring the velocity of projectiles were suggested and tried, but finally the method of Robins was generally adopted by military powers. In a few words, Robins proved that the parabolic theory, as applied to projectiles with low velocities, was not far out of the way, but that when

applied to rapidly moving bodies, it was utterly false, and that the fallacy was principally due to the resistance of the air, and that this resistance increased with enormous rapidity with the increase of velocity.

I will now describe the apparatus by which, in the main, he laid the foundation of modern gunnery. You all know what influence "handicapping" has upon the speed of race horses. Robins handicapped his swiftly moving projectiles until their speed was reduced within the scope of his instrument, and then, knowing the exact influence of his added weight, of course the original velocity became known. In explanation, to use our school-day terms, if one body strike another, the momentum lost by one is gained by the other, but the total remains unchanged.

Dependent upon this principle, Robins constructed his *Ballistic*

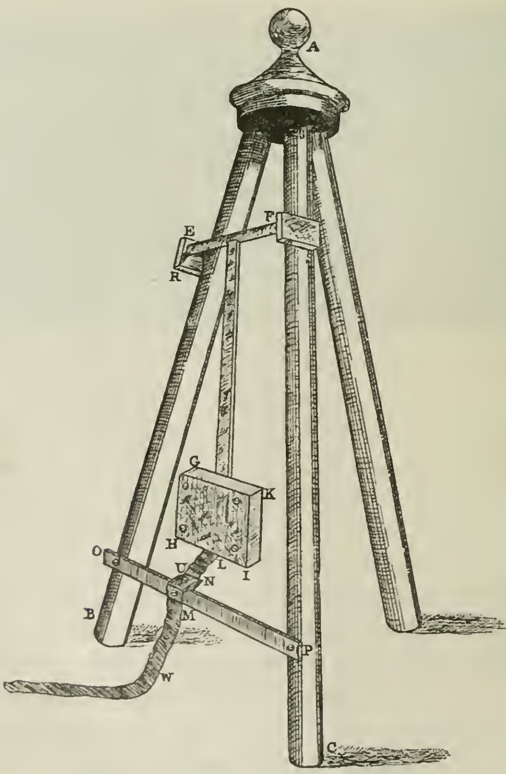

FIG. 2.—Robins's Ballistic Pendulum.

Pendulum—the instrument before you—to gunnery what the mariner's compass has been to navigation.

It is merely an iron pendulum, whose "bob" is faced with a thick piece of wood; to this a narrow ribbon is appropriately attached, which by "paying out" measures the extent of the vibration or swing.

The bullet is fired into the wooden block wherein it lodges; it imparts the whole of its motion to the pendulum, the resulting known momentum is equal to the momentum of the bullet at the instant of impact, and the velocity of the projectile is determined.

If W = weight of pendulum,
w = weight of projectile,
v = velocity of projectile,
V = velocity of pendulum

$$w\,v = (W + w)\,V,$$
$$v = \frac{W + w}{w}\,V.$$

The weight of the pendulum and the distances of its centres of gravity and oscillation must be known. The centre of gravity is readily found, directly by balancing the pendulum on a knife-edge, or indirectly, by bringing it to a horizontal position by means of a cord, fastened to the end opposite the axis, passing over a pulley, and carrying a compensating weight; for then the weight of the pendulum is to the suspending weight as the whole length of the pendulum is to the distance of the centre of gravity from the axis. The centre of oscillation, or that point where, if the whole mass of the pendulum were collected and suspended by a thread from the axis, the angular velocity would be the same under the same initial circumstances as that of the whole pendulum, or, in homely phrase, the "bob" of the corresponding simple pendulum is located by the formula $l = \pi^2 g t^2$. t is found by observing the time of a large number of oscillations.

Robins's pendulum weighed 56 pounds 3 ounces, its centre of gravity was 52 inches from the axis, and it made 200 "swings" in 253 seconds. Hence its centre of oscillation was 62⅔ inches from the axis.

The centre of the wooden facing, or "bull's-eye," was sixty-six inches from the axis, (in later constructions it was made coincident

with the centre of oscillation, and does not possess the property of the centre of oscillation) of moving under impact, precisely as would the whole pendulum. A correction must therefore be made. The *resistance to rotation* at this point must be exactly the same as at the centre of oscillation; or, in other words, the *moments* of *inertia* at the two points must be equal. The usual formula of Mechanics,

$$W k^2 = \Sigma w r^2,^*$$

gives the weight to be considered at the centre of the bob, which, in this case, is 42 pounds ½ ounce. That is, the pendulum will resist movement when struck in the bull's-eye precisely as if *this* weight were concentrated there and the balance taken away. If a "twelve to the pound" bullet were fired, $\frac{1}{504}$ of forty-two pounds, the centre of oscillation will move with $\frac{1}{505}$ of the bullet's velocity of impact, whence, if its velocity be multiplied by 505, we have the velocity of the projectile. The length of ribbon "paid out" gives by reduction the chord of the arc of oscillation due to the impact of the shot, and as its radius is given, we know the versed sine, which is the perpendicular height through which the centre of oscillation has moved, and the *time*† in which it has attained this height is, of course, the same as if it had freely *fallen* through this distance. Therefore, the time and the space being known, the velocity is also known. Robins considered the precision of his device very great. In his own words: "In a bullet moving with a velocity of 1,700 feet per second, the error in the estimation of it need never exceed its $\frac{5}{100}$ part."

For over 100 years, a period that included great revolutions and wondrous campaigns, nothing practical was done in this branch of investigation, the complete record of the power of one of the mighty agents of progress, except a studious following in

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* k, the radius of gyration, is a mean proportional between the distances of the centres of gravity and oscillation from the axis, hence

$$k^2 = 52 \times 62\tfrac{2}{3},$$

but k is also the length whose square is the mean of the squares of the distances of the elementary equal masses from the axis, hence the above equation, from which $\Sigma w = 42{\cdot}03$ pounds.

† $t = \sqrt{\frac{2h}{g}}$

the footsteps of Robins, except the elaboration and development of the Ballistic Pendulum. As evidence of the slow and guarded growth of this only correct method of determining the force of fired powder, the true basis of modern ballistic science, I will again quote from De Tousard's "American Artillerists's Companion," published in 1810. In his Introduction, the author says: "Artillery had its infancy in common with all other sciences, but its progress toward improvement was much slower. Let us not be guilty of the reproach cast [heretofore] on military men [their dislike to innovation], but let us rather endeavor to enlighten ourselves by taking advantage of the experiments and information of all the military and well-informed nations of Europe. Let us not return to those times in which artillerists believed in the rectilinear motion of projectiles, and afterwards in the parabolic motion; lest, like them, we may be obliged, after two or three centuries, to abandon these absurd opinions. Benjamin Robins shall be our guide."

And yet in the two bulky volumes of this work not a word is said of the Ballistic Pendulum. This distinguished officer, well educated for his time, writes thus: "The *initial velocities* of shot and shells must be indispensably known before the problems in projectiles can be solved, which are determined from experiments made with skill and discernment, and conducted with care and circumspection; first, by measuring their penetration into a homogeneous, but of a known consistency; second, by analyzing and resolving into its simple movements the curve described by the projectile on quitting the piece; third, by deducting it from the thickness of metal of the firearm when it is in equilibrio with the pressures of the elastic fluid in every point of its length."

What this means I do not know, and I don't believe the author knew, either.

In another place De Tousard says: "For the moment, we will only mention that it appears at least extremely difficult to find, either by theory or by experiments, the initial velocity of a ball at its quitting the gun; and that the numerous and unconquerable difficulties which present themselves in the solution of this problem must cause it to be looked upon as nearly impossible."

I can reconcile these later utterances with the tribute to Robins in the Introduction, only on the assumption that during the

interval the patriotism of the author of the "American Artillerists's Companion" asserted itself, and that he rejected the entire groundwork of modern accurate practice because it was "English," not a tenable reason nowadays.

Once, while walking in the cemetery at Munich, I came upon a stone graven with the simple words, *Frauenhofer—approximavit sidera*, a complete record of his life-work. With equal terseness may we summarize Robins's labors, "He made shooting a science."

Charles Hutton began at Woolwich, in 1775, his "New Experiments in Gunnery," for which he received, as had his predecessor, the gold medal of the Royal Society.

In his works, Tract 34, he writes: "The object of those experiments was the determination of the actual velocities with which balls are impelled from given pieces of cannon, when fired with given charges of powder. They were made according to the method invented by the very ingenious Mr. Robins, and described in his treatise on the 'New Principles of Gunnery,' of which an account was printed in the 'Philosophical Transactions' for the year 1743. Before the discoveries and invention of that gentleman, very little progress had been made in the true theory of military projectiles. This book, however, contained such important discoveries that it was soon translated into several of the languages on the continent, and the late famous Mr. L. Euler honored it with a very learned and extensive commentary, in his translation of it into the German language. That part of Mr. Robins's book has always been much admired, which relates to the experimental method of ascertaining the actual velocities of shot, and in imitation of which, but on a larger scale, those experiments were made which were described in my paper. Experiments in the manner of Mr. Robins were generally repeated by his commentators and others, with universal satisfaction; the method being so just in theory, so simple in practice and altogether so ingenious, that it immediately gave the fullest conviction of its excellence and the eminent abilities of the inventor. The use which our author made of his invention, was to obtain the real velocities of bullets experimentally, that he might compare them with those which he had computed *à priori* from a new theory of gunnery, which he had invented, in order to verify the principles on which it was founded.

"The success was fully answerable to his expectations, and left no doubt of the truth of his theory, at least when applied to such

pieces and bullets as he had used. These, however, were but small, being only musket balls of about an ounce weight; for, on account of the great size of the machinery necessary for such experiments, Mr. Robins and other ingenious gentlemen, have not ventured to extend their practice beyond bullets of that kind, but contented themselves with ardently wishing for experiments to be made in a similar manner with balls of a larger size. By the experiments described in my paper, therefore, I endeavored in some degree, to supply that defect, having used cannon balls of above twenty times the size, or from one pound to near three pounds weight. These are the only experiments that I know of, which have been made in that way with cannon balls, though the conclusions to be deduced from such a course are of the greatest importance in those parts of natural philosophy which are connected with the effects of fired gunpowder; nor do I know of any other practical method besides that above, of ascertaining the initial velocities of military projectiles, within any tolerable degree of the truth, except that of the recoil of the gun, hung on an axis in the same manner as the pendulum, which was also first pointed out and used by Mr. Robins, and which has lately been practised also by Benjamin Thompson, Esq., (now Count Rumford), in his very ingenious set of experiments with musket balls, described in his paper in the 'Philosophical Transactions' for the year 1781. The knowledge of this velocity is of the utmost consequence in gunnery; by means of it, together with the law of resistance of the medium, everything is determinable which relates to that business; for, as remarked in the paper above-mentioned on the first experiments, it gives us the law relative to the different quantities of powder, to the different weights of balls, and to the different lengths and sizes of guns; and it is also an excellent method of trying the strength of different sorts of powder. Besides these, there does not seem to be anything wanting to answer every inquiry that can be made concerning the flight and ranges of shot, except the effects arising from the resistance of the medium." Hutton first developed the *Gun Pendulum*, just alluded to, and used it in conjunction with the Ballistic Pendulum. The gun to be fired is suspended as a pendulum, and the observation of the arc of recoil enables us to determine the velocity of the projectile, from the simple axiom that action and reaction are equal and contrary. The weight of the ball is to the weight of the gun, as the velocity of the gun is to the

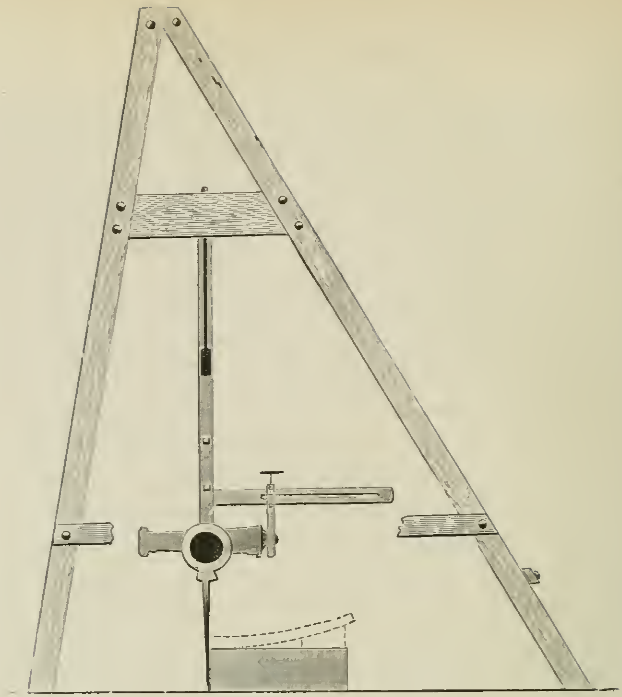


FIG. 3.—Hutton's Gun Pendulum. Side View.

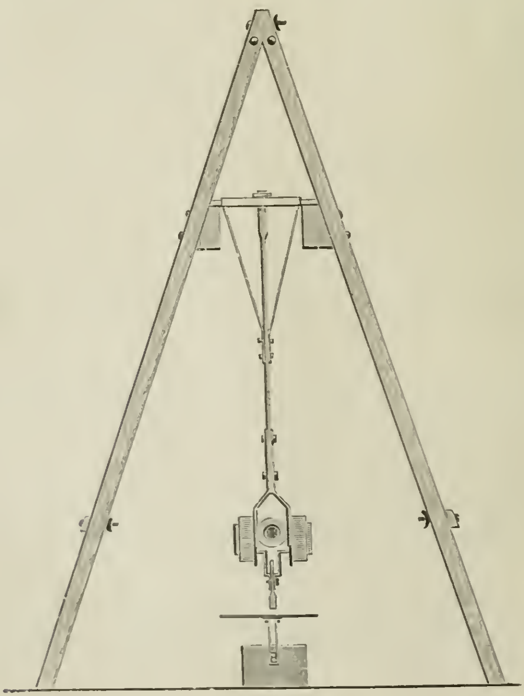


FIG. 4.—Hutton's Gun Pendulum. Front View.

velocity of the ball, provided the weight of the powder has had no effect upon the recoil. Hutton's pendulum weighed 700 pounds, and its centre of gravity was six and two-thirds feet from the axis of suspension.

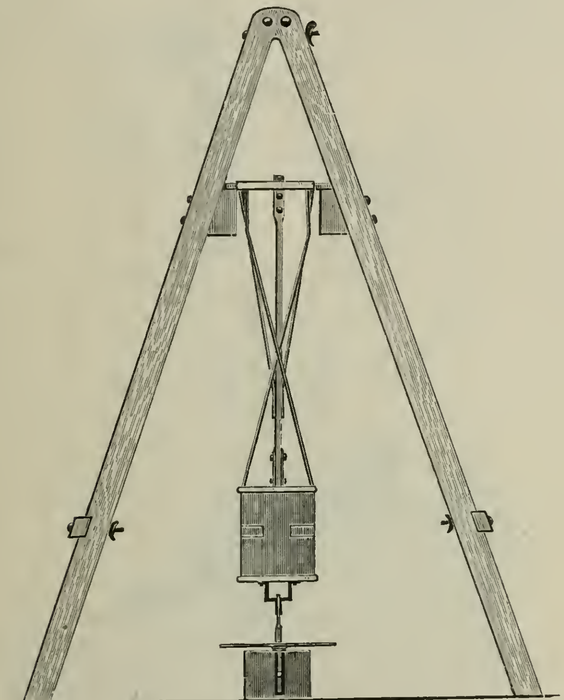


FIG. 5.—Hutton's Ballistic Pendulum.

As stated by Hutton, the objects of these experiments, extending from 1775 to 1790, were the investigation of every circumstance necessary to be known for the improvement of artillery, and, he adds, "The effects of most of these circumstances are determined by the actual velocity with which the ball is projected from the mouth of the piece." The capacity of the Ballistic and Gun Pendulums was gradually increased. At Metz, in 1839 and 1840, twenty-four pounder guns were "slung" and fired, but progress finally culminated in the structures erected at Washington Arsenal, where, from 1842 to 1847, a most exhaustive series of experiments were conducted by Major Alfred Mordecai, a distinguished officer, who has been for many years, and is now, an honored resident of

this city. He experimented with guns as large as thirty two pounders, weighing about 7,700 pounds; his Ballistic Pendulum weighed over 9,300 pounds, and its centre of gravity was over fourteen feet below the axis of suspension. Mordecai's work,

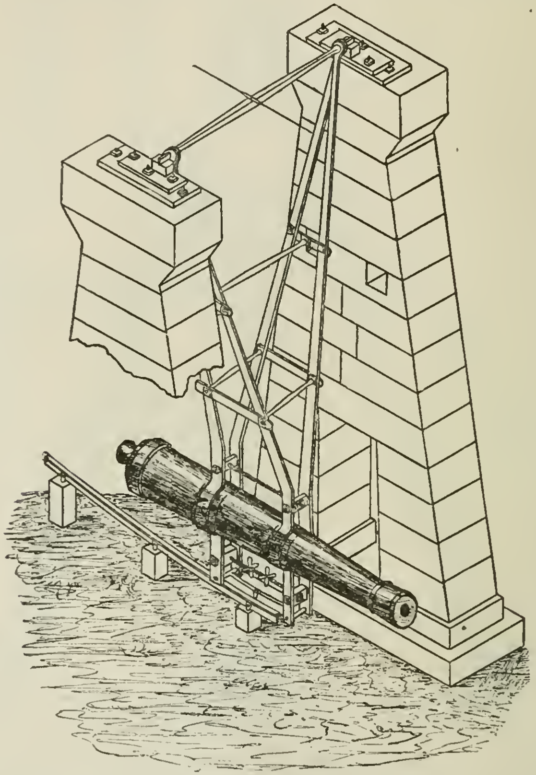


FIG. 6.—Mordecai's Gun Pendulum.

"Experiments on Gunpowder," is classic, and his conclusions cover, amongst others, the following points:

The proof of gunpowder;
Hygrometric tests;
Proportions of ingredients;
Mode of manufacture;
Density;
Size of grain;
Charges for cannon and small arms;
Cartridges for cannon;
Windage of balls;

Loss of force by vent;

Effect of wads, etc.

Major Mordecai reached the practical limit of the performance of the Robins apparatus. You have seen how rapidly the weight and length of the pendulum increased with increasing weight of projectile—Robins, fifty-six pounds per ounce balls; Hutton,

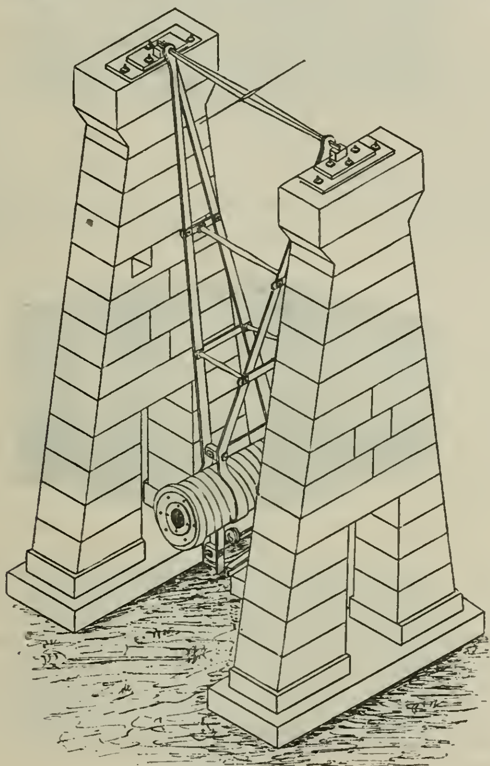


FIG. 7.—Mordecai's Ballistic Pendulum.

700 pounds for three pound balls, and Mordecai 9,400 pounds for thirty-two pound balls. To determine the velocity of a modern 1,000 pound projectile fired from a 100 ton gun, by this method, we should have to ask Colonel Roebling to build available Brooklyn Bridge towers, between which to swing our pendulums.

As late as 1851, Sir Howard Douglass, a distinguished authority, in his well-known "Naval Gunnery," mentions no other method of determining initial velocity than by means of the Robins pendulum.

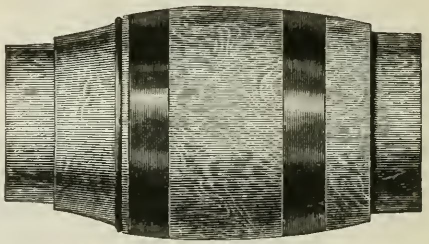
(*To be continued.*)

TESTS OF VEHICLE WHEELS.

By Howard M. DuBois.

[*A Paper read before the* Franklin Institute, *at the Stated Meeting, May 19, 1886.*]

Since the primitive method of overcoming friction by the use of the wheel and axle, much thought has been spent on the mechanical structure of the wheel. Years ago, it reached a point beyond which it seemed impossible to improve. In this shape we have the wheels with which we are most familiar to-day, consisting of a wooden centre or hub into which radiating spokes are driven, supporting the rim or felloe, the whole bound together by a metal

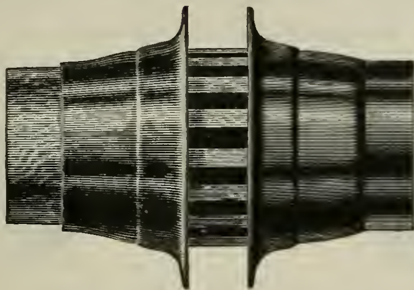


Banded Wood Hub. Test Nos., 3, 9 and 10.

band or tire. A counterpart of this in lighter proportion is the wheel most popular for fine carriage work to-day. In this shape and made of the best material and by experts it possesses all that is requisite for the service required. When made from poorer material and when mechanical rules are not observed in its construction instead of being strong and durable, it becomes soon unserviceable.

As the roads of our country are not all smooth and easy riding, it soon became evident that something more lasting and of stronger construction was necessary, and many different forms were invented. As all of these refer to the placing of the spokes in the hubs, we will briefly review the various principles involved. First, we have what is termed the Sarven principle, so named from its inventor. This consists of a series of spokes driven into a small wooden core and mitred to form a solid arch of wood around this core. Against the back and face of these spokes, a metal flange is

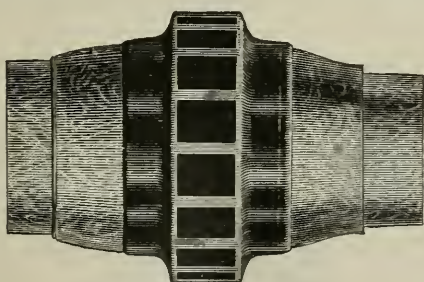
forced by hydraulic pressure and securely riveted, forming what would seem an indestructible wheel. But in practice this wheel



Sarven Hub. Test Nos., 2 and 6.

develops several peculiarities, and while the wheel itself was undoubtedly made stronger, it made the strain upon the axles more severe, as we will describe further on.

A second principle is called the Warner principle, also named from its inventor. This consists in driving the spokes through a metal mortise ring into a wooden hub. This was also a mechanical device more strong than the plain wooden hub wheel first described; but this, while not being so rigid and stiff as the Sarven, still conveyed the vibration of rapid motion to the carriage body,

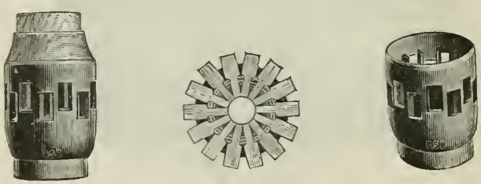


Warner Hub. Test No., 8.

and the fact also was manifested by the more rapid wearing of the tires and rims than was the case under the older conditions. After years of trial both these systems have been condemned for carriage wheels, while steadily increasing in popularity as wheels for conveying merchandise and heavy burdens.

The latest form of construction for carriage work, the invention of Mr. Jared Maris, of Columbus, O., is called the "B. S. B," or Brown's shell band wheel, and consists of a metal shell from which

projecting ribs enter the hub, and form a solid metal wall, the spokes entering the hubs thus protected at their full size, this being an exceedingly strong arrangement of this part. With so many varieties of carriage wheels in use, it becomes almost a necessity to have some kind of scientific test made whereby an accurate

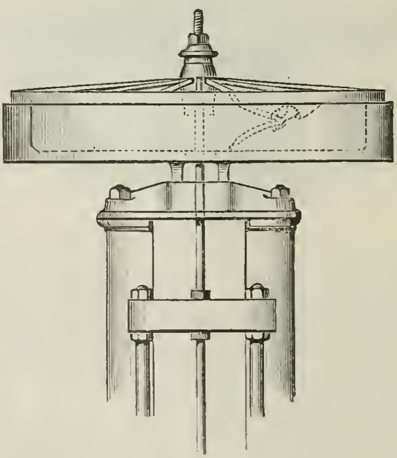


B. S. B. Hub. Test Nos., 1 and 5.

idea might be obtained of the carrying capacity of the various dimensions of wheels, and also that some of the reasons might be made clear why wheels made in one way should not produce the same satisfactory results as in some other form. With this end in view, the writer was selected by several of the largest manufacturers of wheels in this country to conduct an exhaustive series of tests for this purpose.

HOW THESE TESTS WERE MADE.

Having received an assortment of wheels, all uniform in size and general dimensions, and representing all the various kinds of



Attachment to Testing Machine.

vehicle wheels in common use, after due consideration it was decided that each specimen should be tired as for regular travel and subjected first to a test of the amount of weight it would take to "dish" the wheels backward one and one-fourth inches, this being the extreme practical limit, or the point at which the tire ceases to be a factor. After reaching this point, the wheels were to be released from pressure and a measurement made to see with what amount of elasticity the wheels returned to their normal condition. After this, upon a second application of pressure, it was thought to establish some point where wheels sustained rupture or became wholly useless.

To determine these points, the testing machine of Messrs. Riehlé Bros. was secured, this elaborate weighing machine being the one adopted by the United States Government as a standard. To adapt this machine for specimens so large as carriage wheels four feet in diameter, required a special face plate or casting just

One of each Main Division of Test of Wheels into Dish to determine Elasticity.

No.	1	2
Style of Wheel...........	B S B	Sarven.
Original Dish......	$\frac{1}{2}$	$\frac{7}{16}$
Number of Spokes.......	14	16
Pressure into dish @ $\frac{3}{4}$ in.	330	400
" " $\frac{7}{8}$ "	570	620
" " 1 "	730	900
" " $1\frac{1}{4}$ "	1050	1150
After pressing into dish 2 inches, Wheel returned to................	$\frac{5}{8}$	$1\frac{1}{8}$

the diameter of the wheel, which was made with a raised rim or edge four inches higher than the face. Upon this rim or edge the wheels were placed face downward, and a bolt with a broad washer was placed through the centre of the wheel, and to the bolt the pulling strain was applied, the weight to the fraction of a grain being recorded upon the balance scale rod below.

Each specimen so tested was labelled and numbered, the accompanying diagram giving the weights and figures as taken.

WHAT THE TESTS DEVELOPED.

These tests developed the fact that wheels are arbitrarily divided into two grand divisions, namely, those having spokes driven in

straight lines, and those whose spokes are stepped or staggered. To make this more clear, we will state that resistance to pressure alone is not all that is required in a carriage wheel. Were this the case, the solid circle cut from a single piece would lead the tests. The most important factor in a carriage wheel is elasticity, or power to dissipate jar and vibration without conveying the same to the axles and springs, just as some substances are better conductors of heat and electricity, so some forms of constructing wheels are better or worse conductors of vibration. These tests prove then that all wheels in which the spokes are staggered, possess the power to resist strain and return to their normal condition, while those belonging to the other grand division, or those having the spokes standing in a straight line, while resisting pressure almost equally, do not return; or, in other words, do not possess the proper amount of elasticity to fit them for carriage purposes.

Again, we find this question of elasticity is affected to a great extent by the amount of free space between the hub and the rib of the wheel. We find in those wheels that the iron projecting above the hub clamps the wood of the spoke, stiffening the same until the vibrations are shortened, thus accounting for the more rapid crystallization of the steel in the axles used with these wheels than where the B. S. B. or plain wood hub is used. For ordinary use in the carriages, the B. S. B. wheel can be highly recommended, as these tests prove that it possesses, (1), an indestructible hub; (2), it has the same amount of free space between the hub and rim as the plain wood hub, insuring the same ease of motion and freedom from vibration; and, above all, it can be made durable without the close grading of material so necessary to success in the plain wood hub wheel.

These tests can be taken to form the basis of calculation, as the point at which the wheel comes straight or out of dish is nearly uniform, being 300 pounds. This shows that this proportion of spoke can only be depended upon to sustain a strain of 600 pounds, which is equivalent to the weight of two average persons swaying from side to side on springs, such as used on pleasure carriages. Taking these proportions then, we have a starting point from which we can proportion wheels to the loads they are to carry.

The tests were made to determine which of the wheels in common use were the best adapted to the requirements of the case, and

MR. HOWARD M. DuBOIS: PHILADELPHIA, March 30, 1886.

Dear Sir—We have this day tested for you specimens of Vehicle Wheels, with the following result: Test of Various Kinds of Vehicle Wheels in common use, made by Riehlé Brothers on Standard Machine adopted by U. S. Government.

STYLE OF WHEEL.		B. S. B.	Sarven.	Banded Wood Hub.	Wood Hub.	B. S. B	Sarven.	Maris Socket.	Warner.	Banded Wood Hub.	Band Wood Hub Compressed Tenon.
No. of Test		No. 1	2	3	4	5	6	7	8	9	10
No. of Spokes		14	16	14	14	14	16	14	14	14	14
Original Dish		1/2	5/8	3/8	13/32	1/2	1/2	1/2	1/2	1/2	1/2
Press're, lbs.	200	5/16	1/4	1/8	1/8	1/4	1/8	3/8	1/8		
1st Test.—From Original Dish to 1¼ in. back; then pressure relieved, to determine how near Wheels return to Original Dish. 2d Test.—Pressed Wheel back to 4 or 5 in. unless sooner broken.	250	5/16	1/4	1/8	1/8	1/4	Straight	1/4	1/8	Tested to determine comparative holding powers of Tenons.	
	300	Straight	Straight	Straight	Straight	Straight	back 1/8	back 3/8	Straight		
	400	back 1/8	back 5/16	back 3/16	3/16	"	" 1/4	1/2	back 3/8		
	500	" 3/8	" 5/8	" 3/8	back 3/16	back 1/4	" 1/2	back 5/8	" 1/2		
	600	" 9/16	" 3/4	" 9/16	" 7/16	" 7/16	" 5/8	" 3/4	" 11/16		
	700	" 5/8	" 15/16	" 13/16	" 9/16	" 5/8	" 3/4	" 7/8	" 3/4		
	800	" 3/4	" 1	" 15/16	" 11/16	" 3/4	" 7/8	" 7/8	" 7/8		
	850	" 13/16	" 1	" 1	" 3/4	" 13/16	" 7/8	" 1	" 7/8		
	900	" 7/8	" 1 1/16	" 1 1/16	" 13/16	" 7/8	" 1	" 1 1/16	" 1 1/16		
	1000	" 15/16	" 1 1/8	" 1 1/8	" 1	" 1	" 1 1/16	" 1 1/16	" 1 1/8		
	1050	" 1	" 1 3/16	" 1 3/16	" 1 1/16	" 1	" 1 1/8	" 1 3/16	" 1 1/8		
	1100	" 1	" 1 1/1	" 1 1/4	" 1 1/8	" 1	" 1 1/8	" 1 3/16	" 1 1/8		
	1300	" 1 1/4			" 1 3/8	" 1 1/4	" 1 1/4	" 1 1/4	" 1 1/8		
Dish on 2d test after going back		" 1/2	" 3/16	" 1/4	" 11/32	" 1/2	" 3/8	" 7/15	" 5/16	Back 5 in.	Back 5 in.
2d Test		Back 4 in. Press're 2400 lbs. (1)	Back 4 in. Press're 2400 lbs. (2)	Back 4 in. Press're 2000 lbs. (3)	Back 3⅛ in. Press're 1950 lbs. (4)	Back 5¾ in. Press're 2600 lbs. (5)	Back 4 in. Press're 2650 lbs. (6)	Back 4 in. Press're 2200 lbs. (7)	Back 2⅛ in. Press're 1550 lbs. (8)	No. 9 Three Spokes drawn from Hub and one started.	No. 10 Eleven Spokes drew from Hub.

1 Returned to original Dish sound in every part ...... 2400 lbs.

2 Sixteen Spokes drew from Hub .... 2400 lbs.

3 Two spokes started from Hub and one split .... 2000 lbs.

4 Wheel collapsed, Hub split ...... 1950 lbs.

5 Two spokes broke in Barrel, but sound in Hub .... 2600 lbs.

6 Rivets pulled and spokes broken................ 2650 lbs

7 One spoke started.. 2200 lbs.

8 One spoke broke and eight drew from Hub.................. 1550 lbs.

Wheel No. 5 was placed under pressure, with supports placed under Spokes at 1 foot from the Hub, and resisted a pressure of 3750 lbs., showing no breakage at Hub excepting one spoke drawn out.

RIEHLÉ BROTHERS.

our experiments show that the one, marked No. 1, withstood all the strain and was elastic enough to return to its normal condition, and we think possesses all that is required in a durable carriage wheel, the test showing it in percentage, at least ten per cent. in advance of all others tried.

DISCUSSION.

MR. ROBT. GRIMSHAW.—"Mr. President, I would like to ask if any tests were made of the amount of pressure required to make the outline of the wheel elliptical? As wheels are ordinarily used, there is a pressure placed upon the axle that tends to flatten the wheel; that is, make it out of round. It is very important in using wheels to know what their strength is. If wheels continue to flatten while in service, it will be a great deal harder to haul a load, and for such purposes where there is a very heavy load, the best wheel would be the one which would stand the greatest amount of dish in the manner explained by Mr. DuBois."

MR. DUBOIS.—"I think these tests have been made by Professor Morin, of Paris, but in carriage wheels we have always looked at the wheel tired as being almost a unit. That is, it is impossible to make it elliptical by any weight placed upon it, because it would break before reaching this point. I did make some tests, but did not have enough specimens to continue the experiments to make it more complete, and I propose to do that within the next few months. My remarks referred principally to carriage wheels in which the loads are never sufficient to make the wheel out of true."

MR. CYRUS CHAMBERS, JR.—"As I understand it, the tests are made by simply applying the pressure to the centre of the hub and supporting the rim uniformly throughout its circumference. That is not the strain upon a carriage wheel in practice. I think a very much better test would have been to have supported this wheel on an axle and applied this power to one edge of it."

MR. DUBOIS.—"I made some preliminary experiments in that direction, but found that with the tire on the results were so nearly uniform that there was no difference that I could detect. When the tire is placed on the wheel it limits the strain on the spokes. When the tire is put on, it is given a 'draft;' that is, it is put on hot, and as it cools off it draws the wheel into what we term 'dish,' and, in that shape, if we press the rim of the wheel with any lateral force it would effect the whole wheel. The tire would hold the whole wheel in shape and it would stand just about the pressure applied to it in these tests. I have the data, taken when these tests were made with the axle, and the results are almost uniform, but the experiments were not completed."

MR. CHAMBERS.—"I have made many tests with wheels, and would say that I can very easily take an elastic wheel, apply power to one side of it and make the side opposite to it take a position at angles to the axle. Do you wish us to understand that the more elastic wheel becomes the easier will it make the riding of the carriage? Do you think that elasticity is an important factor?"

MR. DUBOIS—"Decidedly so."

MR. GRIMSHAW.—"Does not the elasticity of the wheel increase the traction of the carriage or vehicle, and will not a carriage with an elastic wheel be harder to haul than one with a rigid wheel, without regard to the ease of those in the vehicle?"

MR. DUBOIS.—"I think the draft might be increased by a wheel that was very elastic; it might assume a position in which it was at angles with the axle, in that case it would increase the draft. But provision is always made for this by setting the wheels, as it is termed, with 'gather.'"

COOLING OF CONDUCTING WIRES IN AIR AND IN A VACUUM.—A platinum wire, 50 centimetres long, and ·04 millimetres in diameter, was enclosed in a glass tube of six centimetres diameter, and traversed by a current of 1·18 ampères. In the open air, at ordinary pressure, the temperature of the wire did not exceed 75° C. On producing a vacuum of $\frac{1}{19000000}$ of an atmosphere, the wire became red hot. By delicate improved apparatus, Bottomley was able to produce and measure vacua of $\frac{1}{30000000}$ of an atmosphere. These results are interesting, for the prominence which they give to the necessity of obtaining as perfect a vacuum as possible in incandescent lamps. For equivalent currents, the temperature rises and the luminous efficiency increases in proportion as the vacuum becomes more perfect.—*L'Electricien, Sept. 26, 1885.*

UTILIZATION OF ATMOSPHERIC HEAT.—M. Tellier has laid before the French Academy a plan for the combined application of atmospheric heat, and of condensation by cold water for raising water from wells. The roof of a shed or small building is composed of tight compartments formed of sheet iron plates, which are riveted at their edges. In each of the compartments a volatile liquid is enclosed, which becomes vaporized by the atmospheric heat, the vapors escaping by tubes, which meet in a common reservoir. Whatever liquid is drawn with the gas, returns to the compartments by a lower tube. The vapor passes from the reservoir to a metallic sphere at the bottom of a well. This sphere has a caoutchouc diaphragm, which can be fitted by its elasticity alternately to the upper and lower hemisphere, so as to move a sliding valve, and by the alternate introduction and condensation of the vapor to raise water in considerable quantities. In one experiment, 1,200 litres per hour were raised from a depth of seven metres.—*Cosmos, Aug. 24, 1885.*

COLOR-SENSITIVE PHOTOGRAPHIC PLATES.

By Fred. E. Ives.

[*A Paper read at the Stated Meeting held May 19, 1886.*]

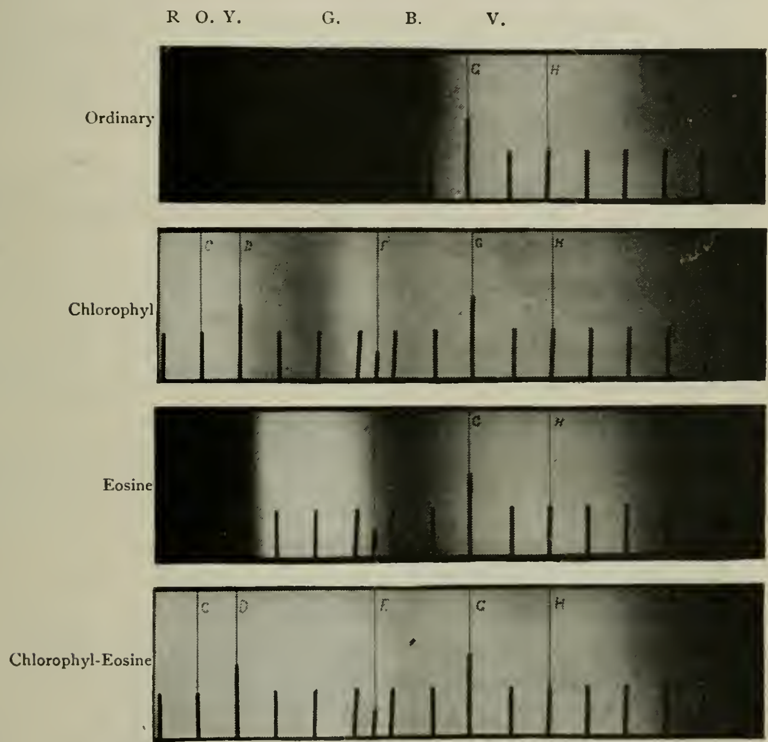
The subject of color-sensitive photographic plates has received a great deal of attention during the past year or two, but there has been and is still a great diversity of opinion in regard to the capabilities of the various color-sensitizers. In illustration of this fact, I will mention that Becquerel, who first tried chlorophyl, stated that with it he made plates from one-fifth to one-tenth as sensitive to the red of the spectrum as to the blue or violet; Dr. Vogel estimated that eosine-stained plates were eight times more sensitive to the yellow-green of the spectrum than to the blue; I myself stated that plates stained with myrtle-chlorophyl, according to my published method, required even less exposure through a yellow glass than eosine plates. Capt. Abney stated that, according to his experience, stained plates were always many times more sensitive to blue and violet than to any other color, and many persons have believed that the color-sensitizers acted more by reducing the blue and violet sensitiveness than by actually increasing the sensitiveness to other colors.

For the purpose of proving the capabilities of chlorophyl and eosine, I have made four photographs of the lime-light spectrum, one on a plain emulsion plate, one on a chlorophyl-stained plate, one on an eosine-stained plate, and one on a plate stained with both chlorophyl and eosine. The spectrum was projected by means of an optical lantern, and a flint glass prism, with a slit measuring one-fiftieth of an inch. It will be understood that the different colors have not exactly the same relative intensity in this spectrum that they have in the solar spectrum, but the difference is insignificant. Short wires were placed so as to cast shadows on the sensitive plate, to aid in the comparison of results; some of these wires, which I have marked, occupy the position of Fraunhofer lines in the solar spectrum. All plates were prepared with the same collodion bromide emulsion, and received the same exposure and development.

The plain emulsion plate shows very little action, except in the blue, violet and ultra-violet; the maximum of sensitiveness is in

the middle of the violet. (It should be noted here that with gelatine bromide dry plates, the maximum of sensitiveness is in the indigo blue, about *G*, and they are also relatively more sensitive to green and yellow.)

The chlorophyl plate shows a very strong action all through the visible spectrum, strongest in the red, orange and dark green; weaker in the blue and violet, and weakest in the yellow-green.



[Owing to the negatives being too intense to reproduce perfectly by the photo-typographic process, the strongest action in the color-sensitive plates appears relatively less in the illustration than it does in the original negative.]

In the red, below *C*, the plate shows about five times as much sensitiveness as in any part of the violet; in the orange-red, twice as much; in the yellow-green, one-half as much; and in the dark-green, one and one-half times as much. The violet sensitiveness appears to be slightly reduced near *H*. This experiment proves that my chlorophyl plates are remarkably sensitive to all colors, as

I have many times asserted that they were, and that they are twenty-five to fifty times more color-sensitive than those which Becquerel employed in his experiments. They are probably 400 or 500 times more sensitive to red than the same plates without chlorophyl.

The eosine plate shows no action in the red and orange, very little in the yellow, a great deal in the yellow-green, and considerable in the dark-green. The action of eosine is strongest exactly when the action of chlorophyl is weakest; it gives about the same degree of sensitiveness to yellow-green that chlorophyl gives to red, but in a broader band. The violet sensitiveness appears to be exactly the same as in an unstained plate.

The chlorophyl-eosine plate shows by far the most remarkable result of all. Neither sensitizer appears to have retarded the action of the other, but rather to have aided it, so that *the weakest portion of this photograph below F is stronger than the strongest portion in the blue and violet!* Nearly a year ago I recommended that chlorophyl and eosine be used together in practical isochromatic photography, and this experiment proves that the combination possesses the advantages which I claimed for it.

I have found that in order to secure the best results with the chlorophyl-eosine process, fresh, strong blue-myrtle chlorophyl solution must be used, and the amount of eosine must be strictly limited; otherwise, the plate will not be so sensitive to yellow and to blue-green. I now prefer to apply the eosine by simply tinting with it water in which the plate is to be washed after applying a plain solution of chlorophyl. I have an over-exposed negative of a bright chromo-card which I made on one of these chlorophyl-eosine plates, with an exposure of one minute in the light of a coal oil lamp, having a single small argand burner and nickel reflector. No color-screen was used, but, owing to the yellowness of the coal oil flame, all the colors have photographed correctly

An unstained plate (same collodion emulsion), with same exposure and development, showed only the high lights of the picture, very faintly.

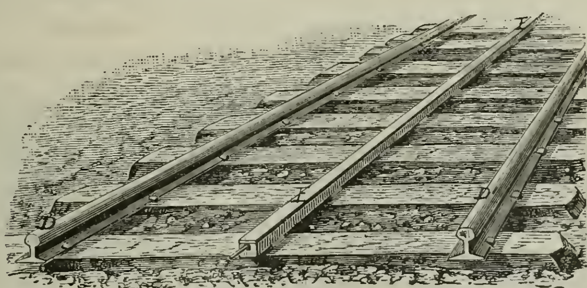
A SPRING NEAR GABÈS.—Commander Landas, who has succeeded Col. Roudaire in the region of the *Chotts*, has found a powerful subterranean sheet of water at the depth of ninety-one metres, which yields not less than 8,000 cubic metres per minute.—*Cosmos, Aug. 10, 1885.*

REPORT OF THE COMMITTEE ON SCIENCE AND THE ARTS ON THE PHELPS INDUCTION TELEGRAPH.

HALL OF THE INSTITUTE,
PHILADELPHIA, October 16, 1885.

The ELECTRICAL SECTION, acting as a sub-committee of the Committee on Science and the Arts, to which was referred for examination the System of Induction Telegraphy, invented by the Mr. LUCIUS J. PHELPS, of New York, presents the following report:

A sub-committee of five members of the Section visited New York September 28th, by invitation of the Phelps Induction Telegraph Company, and inspected the operations on a line worked by this system laid on the Harlem River branch of the New York, New Haven and Hartford Railroad. The inventor, Mr. L. J. Phelps, and the Secretary of the Company, Mr. H. D. Hall, accompanied the committee. The branch has a double track from Harlem to New Rochelle, a distance of twelve miles, and the line is laid for this distance on the up-bound track. It consists of a No. 12 copper wire, insulated with okonite, laid in a groove cut in a 3 x 3-inch spruce strip, upon the top of which is tacked a one-half-inch strip as shown in the accompanying cut.



F

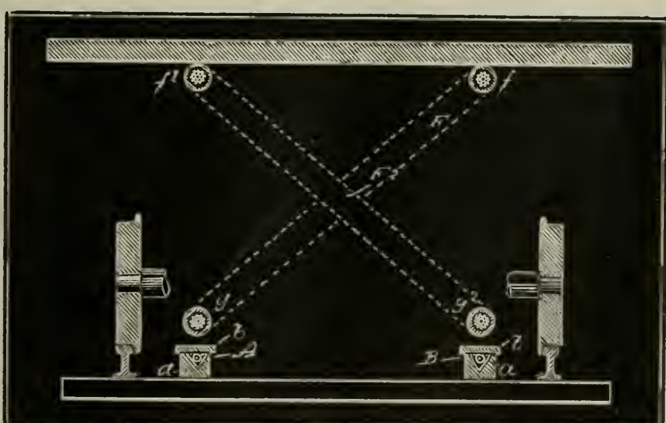
This wire is brought into the station at Harlem, where it is connected with a battery of 150 cells of a modified Bunsen type, and to the ground. It is grounded at New Rochelle, but does not enter the office at that point. A combination car on each of three trains is equipped with the apparatus. An induction coil of ninety turns of No. 14 insulated copper wire passes through a two-inch

iron tube, suspended under the car longitudinally between the trucks about seven or eight inches from the line wire. The upper portion of the coil passes through the car and is hung along the side over the windows. The instruments are set up in the baggage apartment of the car. In a cabinet under the desk is a battery of twelve Bunsen cells.

As the train left the station at Harlem, the committee left messages with the operator at that point, which were promptly sent to the parties on the train to whom they were addressed. Messages were also sent by the committee from the train to various parts of the country, which were received at Harlem and forwarded by other lines. Three members of the committee, who were expert operators, did the most of the work on the train. The messages were received on the car either by the Morse sounder or the telephone, in which could be read the Morse signals. The sender's key, however, instead of simply making and breaking the battery circuit, put in action, when depressed, a vibrator, or "buzzer," which sent alternate positive and negative currents to the line, producing a musical tone in the telephone so long as the key was held down. These rapid breaks were repeated in the induction-coil circuit in which the telephone was placed, on the well known principle that whenever the circuit of a primary battery is broken or closed a current is set up in a parallel circuit at the instant of making or breaking. Without the buzzer it would be difficult to distinguish the dots and dashes in a telephone; with it, the letters can be read with even greater ease than by the ordinary Morse sounder. When the latter is used, a relay is introduced in the coil circuit with a delicately poised polarized armature which responds only to one pole of the battery, and therefore does not reproduce the rapid breaks heard in the telephone. Its movements, therefore, correspond with the movements of the sender's key. It requires a more powerful current to work this relay than is required by the telephone. The battery carried on the car is not sufficient to operate the relay at the Harlem office, and all messages were received at that office by the telephone. This makes it necessary for the operator at that office to be constantly on the watch for business, as there is no means of calling his attention if the telephone is not at his ear. On the contrary, the operator in the car can switch in his Morse apparatus and can hear the call at a considerable distance when the train is moving.

After a stop of a few minutes at New Rochelle, the return trip to Harlem was commenced on the down-track, upon which there was no wire laid. The distance between the line laid on the up-track to the lower portion of the coil when on the down-track was 10 feet 11 inches, yet messages were received quite as well as when the coil was but eight inches from the line, although the tone in the telephone was much weaker, too weak to have any effect upon the relay of the Morse apparatus. It will be seen that the operator at Harlem could not receive messages sent from the train as readily as before, as the effect of the small battery on the car upon the line must have been quite weak; nevertheless, the messages were correctly received. It may be mentioned here that the upper portion of the coil was on the opposite side of the car from the up-track; had it been on the side nearest that track, it would have been nearly at the same distance from the line as the lower portion of the coil, and there would have been no sound in the telephone, as the currents induced in the opposite sides of the coil, being of equal strength, would have neutralized each other.

The test demonstrated the entire practicability of telegraphing between a terminal station and a moving train when but one line is used. If two lines were to be laid, it is evident that there would be an interference between the two in the induction coil on the car unless some means were devised for neutralizing one of them. The system provides for this by so hanging the coils that the two sides will be as nearly equi-distant from the circuit to be neutralized



as possible. With two coils thus arranged, both circuits could be used simultaneously on the same car. The accompanying cut shows the arrangement of the coils.

The system, however, does not seem to provide for the neutralization of the induction from one track line to the other line on the same track, which would be much stronger than the currents from the small battery on the car. For instance, it would be impracticable for the train dispatcher to receive a message from a train while a message was being sent to that train or another train on the other line wire.

If several trains were upon the road at the same time, all would be in electric communication with the train dispatcher by the same wire, but not with each other, because this would require a double induction first from the car to the line and then from the line to the second car, and the battery carried on the car is far too weak to produce any results in the other car. If, therefore, two trains should call the dispatcher's office at the same time, the dispatcher must say which one is first to use the line, as neither train would know that the other was calling.

Your committee does not consider that its duty requires consideration of the many questions of railroad management which would arise if an opinion were to be expressed about the practical application of the system to existing railroad lines. The essential feature of the invention is the utilization of induction to maintain communication between a moving train and the dispatcher's office. That is successfully accomplished by ingeniously constructed mechanism worthy of high commendation. It is for the inventor and railroad managers to find practical use for the new system.

All of which is respectfully submitted.

E. ALEX. SCOTT, *Chairman.*
H. FONDERSMITH,
ADDISON B. BURK,
A. R. KIFER,
ALEXR. E. OUTERBRIDGE, JR.,
JAMES WILSON.

Amended to incorporate a recommendation for the award of the John Scott Legacy Premium and Medal, and adopted as amended.

January 6, 1886. H. R. HEYL, *Chairman*

REPORT OF THE COMMITTEE ON SCIENCE AND THE ARTS ON THE PROCESS AND FURNACE FOR THE REDUCTION OF REFRACTORY ORES, AND THE PRODUCTION OF METALS, ALLOYS AND COMPOUNDS, INVENTED BY EUGENE H., AND ALFRED H. COWLES.

The Chemical Section, acting as a sub-committee of the Committee on Science and the Arts, to which was referred for examination the Cowles process and furnace for the reduction of refractory ores and the production of metals, alloys and compounds; and further, upon the character of the specimens of aluminium bronze, aluminium brass, aluminium silver, silicon bronze, and so forth, as submitted by the company, presents the following report:

There were offered for examination specimens of aluminium ores, aluminium bronze, aluminium silver, aluminium brass, and silicon bronze in ingots, castings, wire and rolled metal, some screws of aluminium brass, knives with blades of aluminium silver and handles of aluminium bronze, and a few other manufactured articles, as well as an ingot of aluminium containing about nine per cent. of silicon. The committee listened to the paper presented to the Institute at its last meeting by Mr. Cowles, and has, since then, made as thorough an examination of the process as was possible in the absence of an opportunity to see the furnace in operation.

Of the patents secured by the Messrs. Cowles, the specifications of the most important three are appended to this report, and cover: "A Process of Smelting Ores by the Electric Current," "An Electric Smelting Furnace," and "An Electric Process of Smelting Ores for the Production of Alloys, Bronzes and Metallic Compounds."

The essential and valuable novelty of the process is the ingenious application of the intense heat obtained by the passage of a powerful current of electricity through a conductor of great resistance, to the reduction, in the presence of carbon, of the most refractory ores, some of which have hitherto resisted all similar attempts at reduction. In this process, the crushed ores mixed

with fine charcoal, and, for the production of alloys, with fragments of copper or some other metal or metals, form the part of the circuit offering the greatest resistance to the electric current, and subjected, therefore, to the highest temperature. The heat developed is so great that nearly all oxides are decomposed, and charcoal is changed to graphite.

The reduction is effected in an oblong, rectangular box, whose interior dimensions are the following : length, 5 feet ; width, 1 foot ; depth, 1 foot. The walls and bottom are constructed of fire-brick, while the top is a cast iron slab. The charge, consisting of copper or some other metal, fine charcoal and the ore to be reduced, occupies, in the central part of the furnace, a space 3 feet in length, 9 inches in width, and 3 inches in depth. Beneath the charge, separating it from the bottom of the furnace and on all sides of it, is a packing of limed charcoal, which prevents loss of heat by conduction or radiation, and protects the fire-brick from disintegration.

Immediately beneath the charge is a layer of pure charcoal, to prevent the introduction of calcium from the limed charcoal into the alloy.

Through each end of the furnace projects a large electric light carbon, called an electrode, extending through the limed charcoal into the charge. More charcoal is added, filling completely the box, the cover is luted on, and a current of 1,200–1,500 ampères, furnished by a dynamo-electric machine, is passed for five hours through the furnace, which is practically air tight, although two or three openings are made through the top to permit the escape of the gases generated during the reduction.

The process is placed under the control of an operator of only ordinary intelligence, with the aid of the ampèremeter, resistance box and electrodes. At the beginning of the "heat," the latter penetrate the charge, and the current passes through only a small portion of the mixture, but they are gradually drawn apart until the entire charge lies within the zone of fusion.

To obtain the product of the reduction it is necessary, at present, to allow the furnace to cool, but the company hopes to make the process continuous. It will then be possible to introduce fresh portions of the charge through openings in the top of the furnace, while the molten alloy may be drawn from the lower part. When ores yielding volatile products are employed, the furnace differs slightly from the one described.

The charge for the production of aluminium bronze consists of fifty pounds of granulated copper, twenty-five pounds of crushed aluminium oxide (corundum) and twelve pounds of a mixture of charcoal and electric light carbon. When the furnace is cleaned. there are found in the lower part about fifty pounds of a copper alloy containing fifteen to thirty-five per cent. of aluminium and a small quantity of silicon. From this alloy, standard aluminium bronze alloys may be prepared by remelting it with the proper amounts of copper. Higher in the furnace is obtained a grayish fused mass, composed of carbon and aluminium, that may prove to be a carbide of aluminium. The latter element is present in quantities varying from thirty to sixty per cent.

The chemistry of the process, so far as it is understood, is simple. The carbon, aided by the high temperature, removes the oxygen from the corundum with the formation of gaseous carbon monoxide. A small amount of aluminium is obtained in grains mixed with charcoal, another portion unites with copper to form the alloy. while the remainder combines with carbon and yields a crystalline compound.

It is possible that electrolysis plays some part in the decomposition, but no proof has yet been given that it does. If copper alone be heated with the aluminium oxide, the reduction does not occur. When corundum is heated with charcoal alone, the aluminium unites with the carbon, yielding the crystalline compound referred to above. The former length of the heat was about one hour, the increase to five hours enlarges the yield of the copper alloy, with a comparative decrease in the yield of the carbon compound.

This process is applicable to the reduction of all kinds of ores, but particularly to those unreducible by other means.

The value of the aluminium bronzes and other alloys containing aluminium is so well known, that we shall say only a few words concerning them. Full and interesting details may be found in metallurgical works, chemical dictionaries, engineering and special text books, as well as in the pamphlet published by the Cowles Electric Smelting and Aluminium Company.

All authorities unite in their praise and predict an extensive use for them. Their high price alone has prevented their general employment, but in spite of their costliness the demand is not inconsiderable. The usefulness of the aluminium bronzes is due to

great hardness, tensile strength and stiffness. They are also ductile, malleable at high temperatures and elastic. They resist the action of the air, moisture and many other chemical agents far better than brass or bronze. The lustre of silver or gold may be given to them. Under some conditions, these metals tarnish more readily than the aluminium bronzes. They may be cast, rolled or forged. The castings are of great strength and homogeneous; repeated melting decreases their tensile strength but slightly without causing any loss of weight. Large castings may be made with care; almost perfect small castings are readily secured. The Messrs. COWLES claim that heavy guns could be cast from aluminium bronze, which would be stronger than guns of forged iron or steel, more enduring and cheaper. A well-known authority calls aluminium bronze "the best bronze yet known."

Aluminium silver, an alloy containing aluminium bronze and nickel is valuable for cutlery. The tensile strength, lightness, non-corrosiveness and electric conductivity of silicon bronze renders it a most desirable substitute for iron and copper in telegraphy and telephony. Aluminium brass far excels ordinary brass in hardness, strength and durability. It is also cheaper. Admitting the great worth of these alloys, let us consider for a moment the important question of their cost.

The works at Cleveland, which are in reality only an experimental plant, produce daily about 400 pounds of aluminium bronze, selling at fifty or sixty cents per pound. The Lockport works will have a capacity of 3,000 pounds per day, and the company expects to sell the bronze for less than forty cents per pound; in fact, Mr. COWLES intimates in his paper that the price may be as low as fifteen cents per pound.

At the present price of aluminium bronze, the aluminium that it contains, costs about $3.80 per pound. Should the alloy be sold for fifteen cents per pound, the aluminium will be sold for about forty cents per pound. The price of aluminium manufactured by other processes is not under $9 per pound. The Cowles Electric Smelting and Aluminium Company promises to furnish within a year pure aluminium for fifty or sixty cents per pound. If raw material of sufficient purity can be obtained cheaply, this can probably be done. Possibly the so-called carbide of aluminium may be employed. It has been already utilized in the manufacture of

an extremely pure chloride of aluminium. In the absence of sufficient information regarding the process for the production of pure aluminium, the committee is unable to discuss the question intelligently. On the other hand, from an examination of an itemized statement, furnished by Mr. COWLES, showing the running expenses for several weeks of the works in Cleveland, and in consideration of the simplicity of the process, the cheapness of the raw material, and freedom from the use of expensive chemicals, the committee believes that the production of alloys and metallic compounds, cheaply and on an industrial scale, is assured. The members of the committee have, moreover, no doubt of the ultimate success of the company in its endeavor to produce pure aluminium at a moderate cost. The scientific possibilities of the inventions must not be overlooked. The intense heat of the electric current is so completely under the control of the investigator, and the other conditions are so favorable, that not the slightest doubt should exist of speedy and valuable additions to our knowledge of metallurgical and chemical processes. Already aluminium alloys of iron, silver, tin, cobalt and nickel have been prepared; silicon, boron, potassium, sodium, magnesium, calcium, chromium and titanium as well as aluminium have been obtained in a free state. An apparently new oxide of silicon awaits study. The opportunities for the formation of new and important alloys seem unlimited, and it is not improbable that some of our elements may be resolved into different kinds of matter.

Much speculation is, however, out of place in a report of this kind; but the committee is of opinion, that the Messrs. COWLES and their associates deserve the highest commendation for their inventions, furnishing, as they do, a distinctly new and important metallurgical process, that will render possible the cheap production of useful alloys, compounds and metals, and giving to science a valuable aid in research.

LYMAN B. HALL, *Chairman.*
HENRY PEMBERTON, JR.,
HENRY TRIMBLE.

Amended to incorporate a recommendation for the award of the John Scott Legacy Premium and Medal to the inventors for their electric smelting furnace; and of the Elliot Cresson Medal, for their

invention of a new process in the metallurgical arts for the reduction of refractory substances; and, as so amended, adopted.

H. R. HEYL, *Chairman.*

Philadelphia, Wednesday, April 7, 1886.

SOME ADDITIONAL FACTS CONCERNING THE REIS ARTICULATING TELEPHONE.

BY PROF. EDWIN J. HOUSTON.

[*Read at the Stated Meeting of the* INSTITUTE, *June 16, 1886.*]

Whatever the decisions of the United States Circuit Courts have been in the past, or whatever they may be in the future, there can be no reasonable doubt, that in the opinion of the general scientific world, to Reis and not Bell will be accorded the credit of having made the great discovery of the methods and apparatus for the electrical transmission of articulate speech.

We have elsewhere maintained the following propositions, viz.:

1st. Reis invented an instrument which he called a telephone, and which he said would transmit speech

2nd. That this telephone operated by means of electricity, and consisted of transmitting and receiving apparatus.

3rd. That in the hands of Reis it did transmit intelligible, articulate speech; and that credible witnesses are still alive who heard it so transmit speech.

4th. That exact reproductions of the Reis apparatus, operated in accordance with his directions, will transmit speech now.

To the above it is answered, despite the published statements of Reis to the contrary,

1st. That Reis devised his apparatus to transmit musical tones, and not to transmit articulate speech.

2nd. That there is but one method by which articulate speech can be transmitted electrically, viz., by an undulatory current, and therefore Reis never could have transmitted articulate speech telephonically, since, it is alleged, he did not use the undulatory current. Any, consequently, who imagined that they heard articulate speech through the Reis apparatus must have been deceived.

3rd. That if reproductions of the original Reis apparatus have

been made to transmit articulate speech, however, exact they may appear, they must have been varied in some important (although inappreciable) respect.

The transparent sophistries of the above answers are, in our judgment completely swept away by the experiments of Mr. John R. Paddock, of the Stevens Institute of Technology, which although of an early date we have but recently received and had permission to publish. These instruments have been introduced into the Overland Telephone Cases, on appeal to the Supreme Court.

Mr. Paddock's experiments appear to clearly establish, what at the outset should have been apparent to any fair inquirer; viz., that *the original Reis apparatus, without any change whatever, will transmit intelligible, articulate speech.*

The apparatus used by Mr. Paddock, were the identical apparatus employed by Reis in his lecture before the Physical Society at Frankfort a-M., in 1861–2. They were obtained by Hon. A. J. Keasbey, from Prof. S. P. Thompson of Bristol, England, who got them from Dr. Theodore Stein, of Frankfort, Germany. Dr. Stein got them from Prof. Dr. Böttger, President of the Physical Society of Frankfort, who received them direct from Reis, after the above mentioned lecture. The story as above told is fully substantiated by testimony taken at Frankfort a-M.

The following letter from Mr. Paddock, will, however, give the particulars at length.

STEVENS INSTITUTE OF TECHNOLOGY,
HOBOKEN, N. J., Feb. 12, 1886.

PROFESSOR E. J. HOUSTON, FRANKLIN INSTITUTE, Phila.

I have read with much interest your articles in the London *Electrical Review* relating to the Telephone and the invention of Philip Reis.

Having facts concerning the same which have not yet been made public and which are of especial interest at this time I take the liberty of placing them at your disposal. In the summer of 1885 I came into the possession of the *Original Bored Block Transmitter* and *Knitting Needle Receiver*, exhibited by *Philip Reis* before the Physical Society, at Frankfort-a-M. in 1861–2. These instruments were obtained by Hon. A. Q. Keasbey, Counsel for the Overland Telephone Companies, from Professor Thompson of Bristol, England, who received them from Dr. Theodore Stein, of Frankfort, Germany, and he in turn from Prof. Dr. Böttger, President of the Physical Society at Frankfort, to whom *Reis himself* gave these instruments after the lecture above referred to. Their history is thus fully proved and their identity has been further established by testimony taken at Frankfort a-M.

The instruments were in a good state of preservation when received by me and required no alterations or additions whatever with the exception of a wooden support for the needle of the receiver which was wanting, and a slight mending of the wooden case which had become broken, evidently during transportation.

With these instruments I soon succeeded in transmitting and receiving good articulate speech. Musical sounds and songs were easily reproduced and it is important to remark that when the transmitter was so operating as to transmit musical sounds *best* it was also so operating as to transmit articulate speech *best*, which in view of the oft repeated statement that the Reis instruments are capable of transmitting *the one*, but incapable of transmitting *the other*, is of especial value as showing that the same condition of the transmitter is required for both. The *pitch* of a musical sound was *not* the only results achieved by Philip Reis with his instruments but also *amplitude* and to a good degree *quality* also, as is proved by the publications of his day (see Annual Report of the Physical Society of Frankfort-a-M. 1861–2. Also, the Deutsche Industrie-Zeitung for 1863)

Mr E. W. Smith, a practical Telephone Operator, assisted me in this work and together we were able to transmit and receive many words and sentences in as *clear* and *distinct* a manner as in any *modern telephone*, and this notwithstanding that the instruments we were using were now nearly twenty-four years old and that the diaphragm of the transmitter was made of a thin animal membrane which soon absorbs the moisture of the breath and then of course loses its tension and fails to respond to the vibrations of the voice.

In describing the operation of this very instrument, Philip Reis in his lecture before the Physical Society at Frankfort makes the following statement:

"If, now, sounds or sound combinations are produced in the neighborhood of the block, so that sufficiently powerful waves reach the opening *a*, then these sounds cause the membrane *b*, to vibrate. At the *first condensation* the *hammer-like wire d*, *is pushed back*, at the *rarefaction* it *cannot follow the retreating membrane, and the current* traversing the strip *is broken*, until the membrane forced by a new condensation again presses the strip (proceeding from *p*,) against *d*. In this way *each sound wave causes a breaking and closing of the circuit*." (The italics are Mr. Paddock's.)

This is the description chiefly relied upon to prove that the Reis instrument operates by means of a *broken current* and hence is incapable of transmitting speech, for it is maintained a current *broken* at each vibration *can not* transmit speech, and Reis distinctly says himself that the current *is* thus broken, therefore, &c.

We have endeavored experimentally to test this most *vital point* so far as regards Reis and his instrument. Whether there are minute breaks in the current during the ordinary use of a Microphone transmitter is a matter still in doubt and one which only indirectly bears upon this question.

The real question is— Did Philip Reis so operate his Telephone as to break the current (as he supposed he did) and if so did he obtain speech in that way—(as he says he did)

We have operated the Reis instruments in *exact conformity* to his description and to *this* very paragraph of that description. When thus operated

"The hammer-like wire *is* pushed back but *can not* follow the retreating membrane and parts from it." A continual humming is kept up as the two platinum contacts strike one-another and a succession of sparks indicate the parting of the electric current at each vibration.

While *so* operating in exact accordance with the description of Reis himself the following sentence has been distinctly transmitted and received

"*William H. Vanderbilt died suddenly at his house on Fifth Avenue, yesterday. He is said to have been worth two hundred million of dollars,*" a sentence of twenty-three words which of itself is clear proof that articulate speech can be transmitted in the Reis instrument when used with the *so called broken current.* We are at present engaged in ascertaining the extent to which this old instrument will transmit speech under these conditions and the work thus far done points to the conclusion that it is far greater than has hitherto been supposed. Photographic records will also be obtained of the vibrations produced under these circumstances which will form an interesting subject for study—and lead to more positive conclusions.

With reproduced forms of a later Reis instrument viz The cubical box form, we have transmitted speech at greater length—one sentence consisting of fifty-six consecutive words. A full statement of these experiments appears in the record of The Overland Telephone Cases, now on appeal to the Supreme Court. With esteem and regards,

Very Truly Yours

JOHN R. PADDOCK,

Instructor in Physics and Chemistry.

The importance of the above statements, substantiated as we do not doubt they will be, can hardly be overestimated. If established, they sweep away completely the broad claims that the Bell Telephone Company have been so pertinaciously endeavoring to establish for Bell. They completely dispel the legal mists, that have so skillfully been maintained around the early labors of Philip Reis, and hasten the time, when the general public, will be ready to do what the general scientific public, the world over, has already done, viz, accord to Philip Reis the credit due to his wonderful discovery.

The importance of Mr. Paddock's experiments will, perhaps, be the better understood by examining some of the recent decisions in the Circuit Courts on the legal value of the Reis apparatus as anticipations of the articulating telephone of Bell.

In the recent New Orleans Telephone decision, in the case of the American Bell Telephone Company, *et al*, vs. the National Improved Telephone Company, *et al*, Judges Pardee and Billings in their decision, spoke as follows:

"From the evidence submitted in the case it seems clear that now, in the present state of the art, neither that Reis' instruments

nor any reproduction of them can be made to transmit articulate speech except by changes of some form in the instruments or by the employment of Bell's method."

"We, therefore, conclude that neither Reis nor his successors anticipated the invention of Bell as set forth in the fifth claim of his application and patent, and as illustrated by Fig. 7, described in his accompanying specification."

But if the original apparatus, without any change will speak, what then?

In the American Bell Telephone Company vs. Amos E. Dolbear, et al, Judge Lowell on Aug. 25, 1883, in giving the opinion of the court in this case said "The defendant now testifies that the Reis instrument can be made to transmit speech, under some circumstances, if operated in the way which Bell has shown to be necessary." * * * * * "The experiment made in the presence of counsel, which was intended to prove the correctness of the defendant's present opinion, was an utter failure. But if it be admitted that the Reis instrument is capable of such use, to a very limited extent, and after a change in its proportions, and when used in a way which the inventor did not intend, still, I am of opinion that it was not an anticipation of Bell."

But if the original apparatus without a change in its proportions, and when used in a way which the inventor intended will transmit speech, what then?

Alluding to the success in making the apparatus described in Fig. 7 of Bell's original specification talk, Judge Lowell says:

"This great result has been reached by Mr. Bell entirely through the improvements described in his second patent (1877 patent) such as the substitution of a metal plate for a stretched membrane, and some others" and these early unsuccessful efforts he says are "now immaterial, for it is proved that the instrument will do the work, whether the inventor knew it or not, and in the mode pointed out."

But if it be now proved that the original apparatus will do the work, which its inventor claimed it would do, (not which he hoped it would do, or was ignorant it would do), what then?

In a case that has been so full of surprises, as the telephone litigations, we must confess to considerable curiosity as to what the courts and the legal advocates of Bell will do with the above evidence.

The author has not personally tried the experiments referred to, but hopes to do so on the first opportunity. Mr. Paddock promises to give him additional information at an early day.

CENTRAL HIGH SCHOOL,
Philadelphia, June 16, 1886.

BOOK NOTICES.

THE PRESERVATION OF TIMBER BY THE USE OF ANTISEPTICS. Samuel Bagster Boulton, Assoc. Inst. C. E. Van Nostrand's Science Series. No. 82. Price, 50 cents, post free.

This little volume comprises an interesting essay on the above subject, read before the Institution of Civil Engineers, and a report of the discussion which followed, in which many prominent members, including the eminent chemists, Dr. Tidy, Dr. Voelcher, and Dr. Armstrong, took part.

The process termed "Creasoting," is the main topic, and the principal question under discussion is, which portion of the "Creasote oils" is the more valuable preservative agent, the lighter portions, containing the carbolic and cresylic acid, or the heavier portion, containing the bulk of the naphthaline?

In England, the use of coal tar creasote has superseded all other methods of wood preservation, and of latter years there has been a strong tendency to increase the proportion of the lighter constituents. The author of the essay contends that this is a retrograde practice, and that the permanence of the preservation by the creasote is thereby diminished.

A wood preservative, to be permanently effective, must be insoluble in water, so as not to be liable to be washed out in damp situations, and to a great extent, non-volatile, especially when the timber is exposed to the summer sun. Carbolic and cresylic acids are soluble and volatile, and therefore may, in a short time, be completely removed from creasoted timbers which have been placed in exposed situations. This is found to be a fact on examination of creasoted timbers in service for about one year, scarcely a trace of carbolic acid being found in them, although the timbers were still in a perfectly sound condition. The more solid substances, as naphthaline, remained in the wood, and further investigation seemed to show that this was the chief preservative agent. In the opinion of the author, with which several speakers coincided, the main object of "creasoting" was to choke up the pores of the wood thoroughly with a permanent solid substance, so that neither air, water nor organic life could penetrate it, and that this substance must also possess antiseptic properties in order to destroy the vitality of germs or organic growth already contained in those pores. It will not do to coat the outside merely with an impervious material, for the moisture and decay producing agents within are thereby retained, especially in green timber, and by this means decay goes on more rapidly than when no preservative has been applied. The crude naphthaline seems admirably fitted for this choking process, being insoluble, only slightly volatile at ordinary temperatures, has antiseptic properties of its own, and has associated with it other bodies, which are also antiseptics. It is necessary that the creasote

should contain some of the lighter oils only for the purpose of rendering the whole capable of thoroughly permeating the timber at the proper temperature. That carbolic acid produces any permanent preservative effect by coagulation of the albuminous constituents of the wood is doubtful, although some believe that this coagulation does take place. Dr. Armstrong, however. "doubts that this takes place to any great extent, or is an essential part of the process."

With the reduction of the proportion of lighter oils, the author recommends a higher temperature for the injection. The usual method is to put the timber in a closed tank exhaust by the air pump run in the creasote heated to a temperature of 100° to 120° F., and then force the liquid into the wood by means of a pressure pump. Mr. Boulton heats the creasote to somewhat over 212° F., and continues the use of the exhaust pump after the introduction of the fluid into the tank. He claims that by this modification the whole of the moisture is perfectly removed even from very wet timber. Much time is therefore saved over the old process when damp timber had to be stacked for several months before being creasoted In regard to the preservation of young wood and sap wood, Mr. Boulton stated that the same creasotes were by his method "always used for both these and old wood and with complete success. It had been clearly established that the heavy oils preserved sap wood from decay." He also added "that the attempt should never be made to inject creasote or any other oily substance without previously or at the time of the operation expelling watery moisture, and that the timber should not be felled while the sap was in it." If an open tank was used for the creasoting more care was required than with the closed tank to obtain good results, and wet timber could not be treated at all, without raising the temperature so high as to cause brittleness. Under no circumstances should the temperature be allowed to rise above 250° F., otherwise the fibre of the timber tends to become permanently injured and weakened.

Mr. Boulton gives a number of striking instances of the durability of creasoted timber. In 1882, he examined eleven specimens of old creasoted sleepers from the permanent way of the London and Northwestern Railway, which had been in use for periods ranging from sixteen to thirty-two years. Also sleepers from the Taff Vale Railway, the Southeastern Railway and the Great Eastern Railway, which had been in use from fourteen to twenty-three years. A portion of the Victoria Dock fence was found to be perfectly sound after twenty-nine years use. All of the above examples were of ordinary Baltic fir. They were all tested for presence of carbolic acid and no tar acid could be found, and it was clearly established that they had been preserved by the heaviest and most solid portion of the tar oils.

At the time of the Paris Exhibition, of 1878, beechwood sleepers creasoted by Mr. Boulton's firm in England, in 1859, which had been in service on the railway from Rouen to Dieppe for twenty years, were examined and not one of them was found to show the slightest trace of decay. This statement was made by Mr. A. Bouisson, of the Western Railways of France. He also states that the company for which he was engineer, had since 1864 applied the creasoting process to about 5,000,000 sleepers, of which at least 3,500,000 were beechwood. In these latter as in the case of the Rouen and Dieppe

line no signs of decay had as yet been discovered, although uncreasoted beechwood was of very perishable nature.

In view of the rapid and alarming destruction of our own Eastern forests and those of Canada and also in view of the fact that the stock of hard woods in our Southern and Western States has already been largely drawn upon, it would be well for American engineers to consider the advisability of the adoption of the creasoting process in this country. R. H.

The Work of the International Congress of Geologists and of its Committees. Published by the American Committee, under the direction of Dr. Persifor Frazer.

Among the sciences, geology is one of the most likely to provoke the proverbial disagreement of the doctors. The expansion of the rocks of a certain horizon at one point, their contraction, or extinction, at another, making that which is in Britain a prominent feature, on the continent an insignificant one, besides the many other causes of difference of opinion, makes an agreement among the geologists of different countries difficult, and possible only by the influence of a feeling among them, that many personal opinions must be held in abeyance in order that the desirable end may be accomplished, an end which all agree would much advance the science.

It is therefore with great pleasure that the scientific world will peruse this pamphlet. In all the discussions the end was kept prominently in view, the salient points on which all, or nearly all, were agreed were fixed and the doubtful ones seem to have been so treated as to conflict seriously with no opinion. Difficult as was this task, it was to an admirable degree accomplished.

The color scale proposed seems well adapted to its purpose, and the proposition to add a significant letter as well as the color will conduce greatly to the clearness of the map, especially, when by age the colors have somewhat changed.

The decisions of the Congress as to the colors were as follows:

"The Carbonic system (or Permo-carboniferous) will be represented by a gray color in three tints."

The color of the Siluric system was left to the choice of the Committee on the Map.

The eruptive rocks will be represented by seven tints, from bright red to dark brownish-red.

Archæan was chosen as the name for the Pre-Cambrian group, and the word group in preference to system.

The division of the Archæan was left to each geologist; the question of sub-dividing the Cambrian and Silurian was deferred.

The determination of other questions arising on the report of the Committee on the Map was left to that committee.

The report of the Committee on the Map is exhaustive and able. Justice cannot be done to it in a brief abstract. Thirty-two sheets of the topographic base for the map are furnished and engraved, leaving but seventeen to be done; but the geological work is much less advanced.

The report of the commission for the uniformity of nomenclature contains many valuable suggestions, and if generally adopted and used will add much to the clearness of geological reports.

Abstracts are given of the reports of the German, the English, the Belgian, the Spanish, the French, the Hungarian, the Portugese, the Roumanian and the Swiss Committees, also a communication from Prof. Renevier upon the monograms decided upon by the commission on the maps to indicate the series of rocks. T. D. R.

Franklin Institute.

[*Proceedings of the Stated Meeting, held Wednesday, June 16, 1886.*]

HALL OF THE INSTITUTE, June 16, 1886.

COL. CHAS. H. BANES, President, in the Chair.

Present—160 members and eleven visitors.

The election of seven persons to membership was reported.

The Secretary, for Mr. JOSHUA PUSEY, read a paper descriptive of a new System of Weather Signalling.

Prof. EDWIN J. HOUSTON presented some additional facts respecting the invention of the Articulating Telephone.

Mr. FRED E. IVES presented a further communication on his researches in Isochromatic Photography.

The above have been referred for publication.

The Secretary read a communication from Mr. J. E. WATKINS, stating the fact that a Section of Steam Transportation (Railways and Steamboats) had been established in the U. S. National Museum, and requesting the coöperation of the INSTITUTE, in suitably setting forth the value of the work which such a section might accomplish, in collecting together and preserving from loss many objects of great historical interest. The communication was accômpanied by several documents, describing the details of the plans it is proposed to follow; whereupon the following preamble and resolution were unanimously adopted, viz.:

"WHEREAS, a petition signed by over eleven hundred (1,100) prominent railway officials of the United States, has been presented in the House of Representatives, by the Hon. J. B. Everhart, and referred to the Committee on Appropriations, which petition reads as follows: 'To the Congress of the United States: The undersigned, desirous of perpetuating the history of the birth and development of Steam Transportation (by Steamboat and Railway), in America, respectfully petition your honorable body to appropriate such a sum of money as may be deemed necessary to carry out the plans recently adopted for the organization of the section of steam transportation in the U. S. National Museum; said sum to be expended under the supervision of Prof. Spencer F. Baird, Secretary of the Smithsonian Institution, and Director of the U. S. National Museum;' therefore,

"*Resolved*, That the FRANKLIN INSTITUTE of the State of Pennsylvania, for the Promotion of the Mechanic Arts, most heartily and cordially concurs in the purpose and objects of this petition, and respectfully requests favorable action thereon."

The Secretary's report embraced remarks on the report of the Engineer Commission on the Panama Canal; on further advances in the production of cheap Aluminium; on Natural Gas, its occurrence and applications; the tunnel under the Harlem River for the new Croton Aqueduct; on Glen & Melville's new proposal in Multiplex Telegraphy; and on the important bearing of the recent judicial decision in England affirming the validity of the Cheesbrough (Sawyer-Mann) patent.

Wm. A. Bigler's Electric Circuit-Making and -Breaking Device, Henry Gut's Ratchet Reamer and Countersink, and Müller's Sectional File were described and exhibited.

The meeting then proceeded to take action upon a number of proposed amendments to the By-Laws, and was thereupon adjourned.

WM. H. WAHL, *Secretary.*

RETRIBUTION BY ELECTRICITY.—During a religious *fête* at Cotopaxi a band of robbers attempted to extinguish the electric lights of the cathedral in order to profit by the confusion and obscurity. The chief put his hands upon the wires with the intention of cutting them, and in doing so he established a current through his body which put him to death.—*Cosmos, Aug. 10, 1885.*

SWISS GLACIERS.—The diminution and retreat of the Swiss glaciers seem to have ceased, and in some instances there has been a marked advance. In the Valley of Chamouni the Argentière has gained ten metres during the past year, and the Boisson has gained forty-five metres. The advance is much more strongly marked in the Western glaciers than in the Eastern.—*Cosmos, Aug. 10, 1885.*

REACTIONS UNDER THE INFLUENCE OF PRESSURE.—When a mixture of carbonate of sodium and sulphate of barium is melted, there is a complete reaction when the sodium carbonate is employed in sufficient quantities. After cooling, the soluble salts can be removed by the aid of water, and the insoluble residue is formed exclusively of carbonate of barium. W. Spring has found a similar reaction, though less complete, from the influence of pressure alone, which is a fact of some consequence in the study of the molecular actions, which take place between solid bodies in contact. He has experimented under pressures of about 6,000 atmospheres, continuing for intervals varying between a few seconds and twenty-four days, and also upon the combined influences of pressure and temperature. In the latter case he has found, as might have been anticipated, that heat exercises an influence opposed to that of compression. These experiments have an obvious bearing upon the diffusibility of matter in a solid state, as well as upon the explanation of some other natural phenomena which are not yet well understood.—*Bul. de l'Acad. de Belg. No. 8, 1885.*

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THE "NOVELTIES" EXHIBITION OF THE FRANKLIN INSTITUTE—1886.

THE "NOVELTIES" EXHIBITION—the twenty-ninth Exhibition held under the direction of the FRANKLIN INSTITUTE, of the State of Pennsylvania, for the Promotion of the Mechanic Arts—was opened on Tuesday, September 15, 1885, and closed Saturday, October 31, 1885.

The following classification was decided upon, viz.:

(1.) Agricultural Machines, Implements and Products.

(2.) Arms, Ordnance, Projectiles, Military Goods and Equipments.

(3.) Caoutchouc and other Plastics, including Vulcanized and Celluloid Manufactures.

(4 *a.*) China, Porcelain.

(4 *b.*) Glass.

(4 *c.*) Lapidary's-work and Glass-cutting.

(5 *a.*) Coal, Minerals and Metallurgy.

(5 *b.*) Metallurgical Processes and Products.

(6.) Distillation, Brewing, Refrigeration and Fermentation-Appliances and Products.

(7.) Drugs, Chemicals, Dye-stuffs, Paints, Soap and Perfumery, and Appliances therefor, and Pharmaceutical Apparatus.

(8.) Electric Lighting, Motors, Dynamos, Generators and Batteries.

(9.) Educational Appliances.

(10 *a.*) Furniture.

(10 *b.*) Carpets and Upholstery.

(10 *c.*) Interior House Decoration.

(10 *d.*) Hats and Wearing Apparel, Umbrellas, etc.

(11 *a.*) Transmission of Power.

(11 *b.*) Steam Engines.

(11 *c.*) Gas Engines and Caloric Engines.

(11 *d.*) Steam Pumps and Injectors.

(11 *e.*) Hydraulic and Pneumatic Machinery.

(11 *f.*) Boilers and Furnaces.

(11 *g.*) Steam Heating and Ventilation.

(12 *a.*) Gas Manufacture for Illumination and Heating, and Apparatus therefor, including Coal and Oil Gas, and Natural Gas Appliances.

(12 *b.*) Gas Utilizing Apparatus, including Heating and Cooking Stoves, Burners for Illumination, etc., Natural Gas Burners and Furnaces.

(12 *c.*) Lamps and other Illuminating Appliances not enumerated above.

(13 *a.*) Machinists' Metal-working Tools and Machine Shop, Foundry and Forge Appliances.

(13 *b.*) Railway and other Transportation Appliances; Elevators, Freight Wagons, Trucks, etc.; Road-making, etc.; Navigation.

(13 *c.*) Coach Work, Farriery.

(13 *d.*) Wood-working and Stone-working Machines.

(14 *a.*) Photography.

(14 *b.*) Fine Arts.

(14 *c.*) Printing, Lithography and Paper Machines and Appliances.

(14 *d.*) Stationery and Paper.

(14 *e.*) Books and Book Binding, Case Making, etc.

(14 *f.*) Fancy Goods, Stationers' Sundries, Sporting Goods and Supplies, Toys, etc.

(14 *g.*) Show Cases and Store Furniture and Service.

(15 *a.*) Textiles and Spun Goods.

(15 *b.*) Carding and Spinning.

(15 *c.*) Weaving.

(15 *d.*) Knitting.

(15 *e.*) Sewing Machines and Sewing Machine Appliances.

(16 *a.*) Surgical and Dental Instruments and Appliances.

(16 *b.*) Philosophical and Optical Instruments.

(16 *c.*) Apparatus and Instruments of Precision.

(17 *a*) Life Saving and Fire Extinguishing and Preventing Appliances.

(17 *b.*) Building Material, Brick, Tile, Terra Cotta, etc.

(17 *c.*) Machines for Manufacturing Bricks, Tile, Terra Cotta, etc.

(17 *d.*) Building Hardware, including Tools for Joiners' use, etc.

(17 *e.*) Plumbing and Sanitary Appliances

(17 *f.*) Housekeeping and Storekeeping Hardware.
(17 *g.*) Scales for Weighing.
(18.) Musical Instruments.
(19.) Machines for preparing Food Products, Confectionery, etc.
(20.) Ladies' Committee.
(21.) Stoves and Heaters, and Materials therefor.

ABSTRACTS OF REPORTS OF THE JUDGES.

GROUP I.—AGRICULTURAL MACHINES, IMPLEMENTS AND PRODUCTS.

Judges:—Israel H. Johnson, Jr., *Chm.;* H. B. Riehlé, Hugo Bilgram, John A. Wiedersheim.

W. L. NASSAU, NEWARK, DEL.:

Williams's Lawn Mowers.—Similar to other machines now in use, although containing some new features in design and construction. By means of two spring supports, one at either end of the cutter-head and containing a number of graded holes which catch on pins or lugs on the frame, the machine can instantly be adjusted to cut grass any desired height. The spiral knife or cutter is made in a special form with a great curve or shearing angle to the stationary cutter, therefore brings less cutting surface in contact at one point than is found in other machines. The cutter-bar is provided with small projections or guards, which prevent the grass from being pushed away instead of being cut, therefore insuring a more even surface to the lawn grass; the cutter-head is adjusted to the cutter bar by means of two adjusting screws. (*A Silver Medal.*)

Williams's Improved Drill Tube.—The foot of the tube is so shaped as to make a flat bottom trench about two inches wide, in which the wheat and phosphates are spread over the entire surface; this giving a better result from the same amount of wheat and phosphates distributed. A wheel is attached to the back part of the drill tube, which acts as a covering device; it is arranged with flanges that throw the soil back in the trench made by the foot of tube, at the same time compresses the soil over the wheat, leaving field in a good shape and further rolling unnecessary. (*A Silver Medal.*)

Approved by Board of Chairmen, November 5, 1885.

H. R. HEYL, *Chm.*

GROUP 2.—ARMS, ORDNANCE, PROJECTILES, MILITARY GOODS AND EQUIPMENTS.

No exhibits.

GROUP 3.—CAOUTCHOUC AND OTHER PLASTICS, INCLUDING VULCANIZED AND CELLULOID MANUFACTURES.

Judges:—Sam'l P. Sadtler, *Chm.*; Henry Morton, W. H. Burk, Wm. C. Head, Horace W. Sellers, Wm. H. Wahl.

CELLULOID MANUFACTURING COMPANY, NEWARK, N. J.:

Celluloid Products.—The Celluloid Manufacturing Company, of Newark, N. J., make a most elaborate and instructive exhibit of what has rapidly developed into a great chemical industry. They show the crude material as turned out from their factory in rods, tubing, sheet and rolls, and a very varied collection of beautiful and useful products manufactured therefrom. The Celluloid Manufacturing Company, of Newark, are the sole manufacturers of the material under the patents of the Hyatt Brothers, issued in 1870, and they give rights to some sixteen separate companies and firms for the manufacture of as many classes of articles from the material. The products of all these subsidiary companies are represented in this exhibit and are described in the illustrated pamphlet issued by the parent company.

The material now known as celluloid was first prepared by an English inventor, Alexander Parkes, about 1855, and introduced by him to the world under the name of "Parkesine." His method at first consisted in preparing nitro-cellulose, or pyroxyline, and then dissolving it in liquid solvents like wood naphtha, mineral naphtha, nitro-benzol, or glacial acetic acid, and then driving off the solvent by evaporation or precipitating the pyroxyline out from the solution as a semi-solid, curdy mass, which is then pressed and dried. Later, he adopted the use of an alcoholic solution of camphor for the solvent. Indeed, the English manufacturers stated that all of the ordinary volatile solvents are improved by the addition of camphor. Parkes abandoned the manufacture in 1867, on account of the difficulties in its manipulation, although he made a fine exhibit of his products at the Paris Exposition, in 1868, obtaining a prize medal therefor. An Englishman, named Daniel Spill, in 1869, revived the use of one of Parkes's methods,

and, indeed, got a patent for the use of camphor or camphor oil in connection with alcohol as a solvent for the pyroxyline, but his patent was afterwards declared valueless by Judge Blatchford, in a suit brought by Spill against the Celluloid Company.

After the failure of Parkes, the first inventor, in making a merchantable article, no new discovery was made in the matter until the Hyatt brothers, then of Albany, N. Y., after considerable experimenting, found that solid camphor, when in the melted state, became a perfect solvent for the pyroxyline, so that by thoroughly mixing the comminuted pyroxyline with camphor and heating, the mass became perfectly homogeneous and plastic. This discovery was patented July 12, 1870, and reissued in an improved form June 23, 1874, and forms the basis of the present manufacture of the Celluloid Company, of Newark. The only other manufacturers of similar products in this country are the American Zylonite Company, of Adams, Mass., who are now the defendants in a suit brought by the Celluloid Manufacturing Company, for infringement of their patents.

It is stated that at the present time there is only one manufactory of celluloid in France, at Staines, on the Seine, and that running under license of the Celluloid Manufacturing Company; that works started in Germany by a Hanover firm, were abandoned because of the explosive character of the material, and that a company recently engaged in its manufacture in England has closed out. The American manufacturers then seem to control almost the entire field. They show evidence, however, by this magnificent display here at the "Novelties" Exhibition, that they are pushing its introduction as a valuable substitute for ivory, amber, rubber and leather with great energy and success.

If we compare the specimens of celluloid materials finished in imitation of ivory with those shown some years ago, when it was first brought to public notice, we can see what decided improvements have been made in its manufacture. The same is true of the excellent imitations of amber, coral and tortoise-shell. The applications in coating linen as a substitute for patent leather, in coating metal in harness trappings as a substitute for both leather and rubber, in the manufacture of celluloid veneers and moulding for picture frames, cornices, panels, etc., in the manufacture of celluloid plates for artificial teeth as a substitute for vulcanite, in

the manufacture of the light but hard celluloid stereotype plates as a substitute for the heavy and easily damaged ones of stereotype metal, and innumerable minor articles here exhibited, all show a marked value, in their serviceableness and adaptability to the uses proposed. Nor must it be overlooked that we have evidence in this exhibit that celluloid is not merely excellently adapted for use as a substitute for other more expensive materials, but has in itself valuable properties possessed by none of the other substances. Thus, on account of its perfect uniformity of color and density, it is better adapted for the manufacture of piano keys and billiard balls than ivory would be. Similarly in the manufacture of trusses it is not merely a substitute for rubber, but possesses decided advantages on account of its strength, perfect elasticity, and freedom from constituents injurious to health.

Some of the applications shown in this exhibit are quite recent, but promise to be of equal importance with those more generally known.

For the completeness and variety of the collection of celluloid products and articles manufactured therefrom, and the evidence of great improvement in the manufacture of a valuable article, and the establishment of new and important applications therefor—

(*A Silver Medal.*)

ISAAC WENDELL, PHILADELPHIA:

Asbestos Praducts.—This exhibit is intended to illustrate what is claimed to be a new article of manufacture, consisting of a mixture of asbestos and various substances, the latter differing according to the several purposes to which the compound may be applied.

The exhibitor claims that it is adapted for journal bearings, for cars, shafting and machinery, spindle steps, steam-pipe covering, crucibles, acid vats, fire-proofing, insulators for all electrical purposes, etc. It is to the compound as prepared for journal bearings that especial claim is made for its usefulness, and for this purpose the mixture consists chiefly of asbestos, powdered and in fibre, plumbago, and silicate of soda.

Without an opportunity to test the properties of these asbestos compounds, it is impossible to determine their advantages.

(*No award.*)

GROUP 4*a*.—CHINA AND PORCELAIN.

Judges:—Wm. A. Porter, *Chm.;* L. W. Miller, John Sartain, Addison B. Burk, Wm. H. Miller.

The judges appointed to examine the articles exhibited in Group 4*a* (china and porcelain) respectfully report that they have made a careful examination of the three exhibits in this group, and are pleased to observe the great advance that has been recently made in the production of useful and decorated ware in china, porcelain and earthenware.

OTT & BREWER, TRENTON, N. J.

Messrs. Ott & Brewer, of Trenton, N. J., exhibited decorated Belleek china in *tête-à-tête* sets, vases and novelties in porcelain; decorated opaque china, in dinner and toilet ware, and decorated white granite in dinner and toilet ware. The Belleek china is a reproduction of the fine porcelain of Belleek, Ireland, and is of such rare beauty that it deserves a title of its own. We do not hesitate to say that the ware is of a superior body to that from which it is named and in strength, delicacy, lightness and marvellous transparency it is all that could be desired. The artistic decoration is also in keeping with the high quality of the ware itself. Many of the vases and art objects exhibited were decorated in raised gold and bronzes of various shades after the manner of the famous Worcester ware. Included in this branch of the exhibit, was a fine bust of Cleopatra, used as a central ornament in the group of objects. Two plaques, decorated in *pâte-sur-pâte*, were also fine examples of artistic work. The great variety of this exhibit precludes a more particular description, but the judges could not fail to be impressed by these evidences of the great strides made in the ceramic manufacture within the last few years. It is only recently that the higher grades of china and porcelain manufacture and decoration have been attempted, and already the exhibit made by Ott & Brewer is fit to be placed by the side of the best work of the European potteries whose products have been imitated.

The decorated opaque china in dinner and toilet ware represents the useful as distinguished from the distinctively ornamental part of the exhibit. The ware is of excellent form and quality, and much of the decoration is highly artistic. The workmanship is all that could be desired. The same may be said of the decorated

white granite in dinner and toilet ware, some of the latter being made very attractive by the delicacy of the ground laying. In view of the high degree of success attained by Ott & Brewer in this most difficult branch of manufacture, we would gladly have them given the highest award at the disposal of the INSTITUTE; but under the limitations set upon the judges, we can only recommend that they be given a silver medal for their very creditable display. If it should be possible to do so, we would also recommend that their claims be referred to the Committee on Science and the Arts for such other award as may be proper for their adaptation of American clays to the production of the finest porcelain.

(*A Silver Medal and recommendation to the Committee on Science and the Arts.*)

J. JEFFRIES & CO., PHILADELPHIA.

J. Jeffries & Co., of Philadelphia, exhibited pitchers, tea-pots, and other articles of domestic use made of earthenware and decorated by colored glazes, or hand-painted on the body, or painted in slip. The ware was of good form and quality, and the decoration simple, inexpensive, and adapted to the character of the ware. The exhibit was creditable. (*A Bronze Medal.*)

GALLOWAY, GRAFF & CO., PHILADELPHIA.

Galloway, Graff & Co., Philadelphia, exhibited vases for interior decoration in the faïence styles. The ware was in general of good form, the background colors, boldly laid on, harmonious in tones of color and the glaze appeared to be of fine quality and suitable to the body.

The plain pieces and those decorated in underglaze are worthy of high commendation. The suggested use of oil colors in decorating these vases, of which samples were also shown for the guidance of purchasers, is not to be commended, since it leads to the use of high colors not compatible with the firing required for underglaze nor in harmony to the educated eye, with the tones which give the highest value to underglaze work.

For the display of undecorated vases and those decorated in underglaze— (*A Bronze Medal.*)

Approved by Board of Chairmen, November 5, 1885.

H. R. HEYL, *Chm.*

4*b*, 4*c*. GLASS, LAPIDARY'S WORK AND GLASS CUTTING.

Judges:—L. W. Miller, *Chm.*; Wm. A. Porter, T. C. Search, Isaac Norris, M. D., Fred. Graff, Addison B. Burk, Samuel Sartain.

The committee appointed to examine groups 4*b* and 4*c*, respectfully submit the following report, that they have carefully examined every exhibit which was assigned to their groups in the classification adopted, which exhibits were as follows:

4b. Glass.

(1.) *Ludwig Moser*, Philadelphia, and Carlsbad, Germany, consisting of glassware from Bohemia, colored, engraved, and otherwise decorated.

(2.) *Tyndale & Mitchell Company*, Philadelphia, china, glassware, and fine pottery.

(3.) *Frank Walcot*, Lyons, France, slagware, imitations of marble or granite ornaments, flower pots, vases, fruit dishes, etc., made from iron and copper slag.

(4.) *T. E. Miles*, London, England, slagware, ornaments, vases, dishes, etc., manufactured from iron, copper and lava slag.

4c. Lapidary's Work and Glass Cutting.

(5.) *James M. Beath*, Philadelphia, lapidary's work, showing the cut of cutting and polishing precious stones.

(6.) *J. E. Mitchell*, Philadelphia, improved high speed grinding machines for opticians' work and other forms of glass cutting.

REGARDING THE FIRST named exhibit, your judges have found it highly interesting, and they desire to express by means of the highest award at their disposal, their appreciation of its conspicuous merit. It consists of beautiful objects, such as vases, pitchers, tankards, goblets, small boxes, etc., sometimes original in design, but for the most part reproductions of rare and precious old Venetain or German work.

To the beautifully colored bodies for whose excellence the Bohemians have long been famous, has been added an exquisite form of decoration in gold and enamel, beautifully executed, the method of applying which is claimed by the exhibitor as his own invention recently patented in Austria and in Germany,

(*A Silver Medal.*)

The exhibit by Messrs. Tyndale & Mitchell your committee find to comprise many novel and beautiful objects for use and ornament arranged with much taste.

(*A Diploma of Honorable Mention.*)

The exhibit of objects made from iron and copper slag, by Mr. Frank Walcot, of Lyons, France, the committee find interesting as an entire novelty, and valuable as an example of profitable utilization of what has heretofore been regarded as waste material. (*No award.*)

The exhibit of Mr. T. E. Miles, of London, England, resembles the preceding one in its general features. (*No award.*)

The exhibit of lapidary's work, by Mr. James Beath, your committee found interesting, not only for the beauty of workmanship by which the objects was characterized, but from the novelty of many of the gems which are now exhibited for the first time, their beauty having been discovered, or at least developed, by Mr. Beath.

Among the stones for which this is claimed are the following:

A sapphire, cut so as to show different colors on the front and back. This effect is often obtained in paste, but has never before been produced, as far as Mr. Beath knows, in the true stone.

American spinels, never cut before.

The collection also embraces jasperized woods of great beauty, hiddenite, agates, American beryls, garnets, amethysts, turquoises, etc.

Your committee find the cutting to be very artistic, some of the portrait heads which were shown being exquisitely wrought.

(*A Silver Medal.*)

Approved by Board of Chairmen, November 5, 1885.

H. R. Heyl, *Chm.*

A Small Incandescent Lamp.—Swan has succeeded in manufacturing a very minute illuminating filament, which requires a current of only 0·14 ampère, with a difference in potential of twelve or thirteen volts (1·8 watt). It gives a light of about a half candle, which is sufficient for an ordinary miners' lamp. Leclanché batteries can be easily made which will give two-tenths of an ampère without polarization. With eighty elements in tension, and a filament requiring 100 volts and 0·15 or 0·20 ampère, one would have a lamp of from fifteen to twenty watts giving a light of five or six candles —*L'Electricien, Sept. 26, 1885.*

// JOURNAL

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The APPLICATIONS of ELECTRICITY to the DEVELOPMENT of MARKSMANSHIP.

By O. E. Michaelis, Captain of Ordnance, U. S. A.

[*A Lecture delivered before the* Franklin Institute, *March 15, 1886.*]

(*Concluded from July issue.*)

I have dwelt somewhat at length upon the development of the method of measuring initial velocity, not only to show the absorbing interest taken in this problem by scientists, not only to show the foundations upon which later modern practice is built, but mainly to show that in all these investigations *powder* was the chief subject. In the "Artillerists's Manual," written in 1859, General John Gibbon, another Philadelphian, by the way, first asserts that the Robins method "appears to have had its day, and to be obliged to give place to one destined, it is thought, to supersede it entirely, and of such accuracy and minuteness in its results as seem to preclude the idea of any further improvements in the measurement of the flight of projectiles. "It is evident," he continues, "that if any machine can be produced for measuring the

flight of projectiles, and can be indiscriminately applied to every gun used as it is in actual service, and be made to exhibit accurately the time occupied by the ball in passing over different parts of the trajectory, the whole problem of measuring the force of gunpowder is solved. * * * Such an instrument has been invented in the electro-ballistic apparatus of Captain Navez, of the Belgian army; and one cannot read the accounts of its wonderful operations without being struck with astonishment that such an instrument should have been invented ten or twelve years ago. * * * without finding its way into this country. * * *." This well illustrates that a prophet may long be without honor in his own country; for, over sixteen years before this was written, a

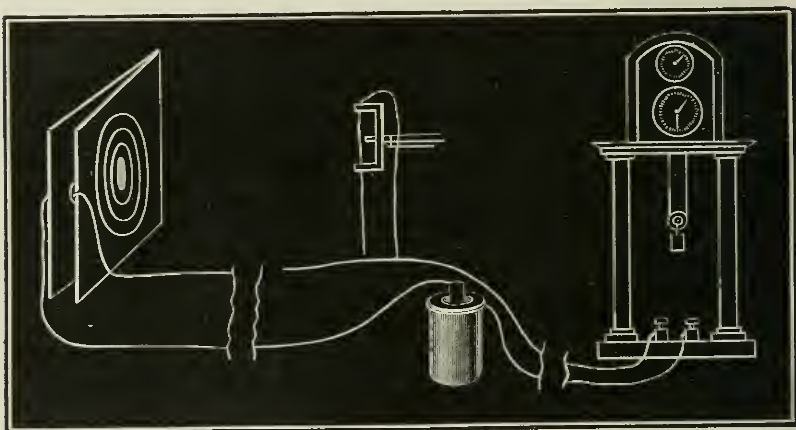


FIG. 8.—Wheatstone's Chronoscope. (Installed.)

great American *savant* published here, in your city, a full description of an instrument that fulfilled all the conditions so well stated by General Gibbon. And now, after "this intolerable deal of sack," I come to the "one half-pennyworth of bread"—the application of electricity to the measurement of initial velocities. Who first suggested this application? Most writers appear to agree that the honor belongs to Wheatstone, and assign 1840 as the date; still, Germany claims it for Siemens; Russia and France for Konstantinoff and Breguet, a scientific copartnership; and Belgium for Navez.

But we have strong ground for considering our own revered Henry as the deviser of the first complete electro-ballistic chronograph, or instrument for recording by electrical agency the time

occupied by a bullet in its passage between two points, a given distance apart. I will briefly tell you what was proposed in Europe and America, and let you decide the question of priority of invention. Professor Charles Wheatstone first measured the velocity of electricity in 1834, using for the purpose a timed revolving mirror. In continuation of these experiments with the intention of observing and registering minute intervals of time, he undoubtedly projected a "chronoscope," operated by the automatic agency of electro-magnets. He had in view the determination of the time of falling bodies, the observation of the duration of gunpowder explosions, and other delicate investigations. This ingenious device was adapted for the measurement of initial velo-

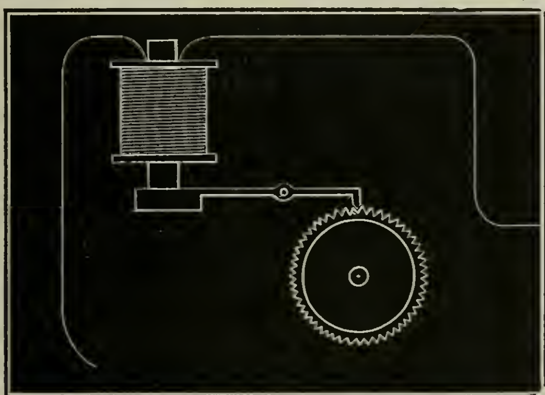


FIG. 9.—Electric Pawl, as applied in Wheatstone's Clock.

cities, but the precise time at which this novel application was suggested, it is difficult to determine. He first *published* an account of this application, induced by circumstances which I will mention directly, in 1845. We know, however, that in 1842, Colonel Konstantinoff, an able Russian artillery officer, visited England, and while there, Wheatstone showed and explained his original chronoscope to him, with inferable consequences that you will see presently. Virtually Wheatstone used a clock, whose train was released by the falling out of gear of the armature of an electro-magnet consequent upon the rupture of a galvanic circuit, and again arrested by the throwing into gear of the same armature upon the re-establishment of the circuit.

You can readily see that the inertia of the train, variations in

residual magnetism, and time required for re-establishing the circuit were sources of error. In the published "Proceedings of the American Philosophical Society of May 30, 1843," is an abstract of Professor Henry's paper, "On a New Method of Determining the Velocity of Projectiles." He used a revolving cylinder, Mattei's apparatus revived, actuated by a clock train so as to make ten turns per second, the surface was divided into 100 equal parts, each part therefore corresponding to the $\frac{1}{1000}$ of a second. Two galvanometers were established close to the cylinder, at opposite ends of a diameter, whose needles were furnished at one end with a pin for making dots on the cylinder. Each galvanometer was in a circuit passing respectively through two screens, a known distance apart, placed in the projectile's path. During the continuance of the currents, the galvanometer needles were deflected against a steady pin, but upon their rupture, the marking ends of the needles were thrown against the cylinder by fine spiral springs coiled about the centre pins of the needles, and thus "dotting" the cylinder. Of course, the position of the dots gave the time of the ball's passage between the screens. I cannot help admiring the completeness of detail of Henry's chronograph, for he provided against almost every instrumental error. His "steady pins" were movable, by which the excursion of the needles could be increased or diminished, and his spiral springs were governed just as are those of our watches. He recognized fully the necessity of the needles describing their small arcs, which need not exceed the one-twentieth of an inch, in equal times. To insure this he brought his two circuits together by a common wire, which dipped into a cup of mercury; this he lifted out while the cylinder was rotating, and adjusted the needles, until the dots were exactly at opposite ends of the diameter. In order that the pins might not obliterate the dots in describing their circles, Henry recommends that the cylinder be also given a slow translating motion. In a subsequent communication to the Recorder, Prof. Henry proposed to substitute induction coils for the galvanometers, whose sparks, upon rupture of the primary circuits, would perforate the graduated paper covering of the cylinder, and added: "In the same way the terminal points of wires from a number of different pairs of screens may be made to impress their marks on the surface of the same cylinder, and the velocity of the ball at

the different points of its path may in this way be determined by a single experiment." Prof. Henry was undoubtedly the first to suggest the application of the induction coil, thus eliminating the errors due to remaining magnetism, and he was the first to suggest an apparatus capable of recording continuing observations on one trajectory. Colonel Konstantinoff, evidently impressed with the feasibility of applying Wheatstone's device to military purposes, at once gave his attention to its modification, and in conjunction with the ingenious Breguet, began at Paris, in June, 1843, the construction of an apparatus that should record many time observations within a single trajectory. This was completed in May, 1844, and it was described before the French Academy, January 20, 1845. In this instrument the records were made upon a revolving cylinder,

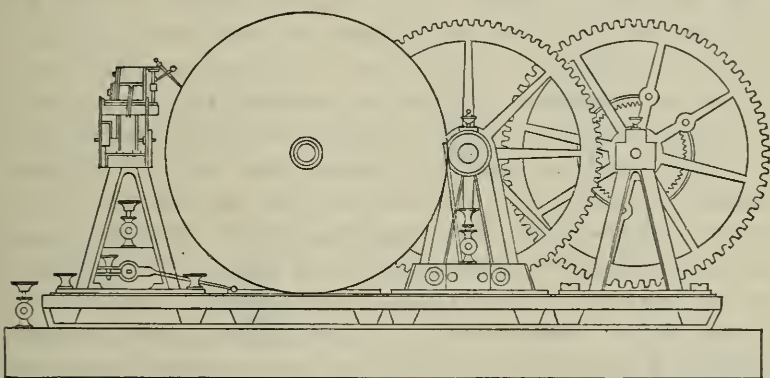


FIG. 10.—Konstantinoff-Breguet Chronoscope.

timed by a Breguet recorder, by styles operated by electro-magnets at the moment of successive ruptures of the circuits. Wheatstone's remonstrance, together with a description of his own apparatus, was presented to the Academy, four months later, May 26, 1845. Konstantinoff's device of 1844, resembled much more closely Henry's, described and published in 1843, than Wheatstone's, described and published in 1845.

The main difference between the Henry and the Paris apparatus lay in the substitution of electro-magnets for galvanometers.

Certainly Henry's suggested use of the secondary current was far more delicate than either, as it avoided the inertia of the needle or the armature, and is the exact method now followed in our most delicate instruments. It seems strange that with the very best

form of electro-ballistic chronograph first described by one of our own people, we have permitted others to carry off all the honor of practically originating, applying and developing, to such an extent indeed, that with one exception—General Benêt's "Electro-ballistic Machines"—Henry's name is not even mentioned by the authorities. Very likely the Mexican war, the discovery of gold in California, Indian hostilities, and the slavery discussion, combined to prevent the evolution of an earlier Edison, who would have made the world ring with the merits of the invention.*

Captain Navez, of Belgium, claims to have had, in 1841, the idea of suspending the moving screen of Colonel Dobooz, already described, by an electro-magnet, but if experiments were made, they amounted to nothing, and certainly no account was ever published. However, an intense impetus was given to the study and development of this branch of applied electrical science, and the next twenty years witnessed the introduction of numberless methods for attaining the desired result in England, Belgium, France, Germany, Switzerland and America. First, Hipp made an important improvement in the Wheatstone apparatus; he so constructed his clock that the train was in continuous movement, the electro-magnets merely throwing a small pinion governing the hands in and out of gear. This instrument you see before you—it is a good representative of the electrical chronoscope, or time-*shower*. In 1848, Captain Navez, probably well-read in the works of Robins and Hutton, devised an electro-ballistic pendulum, which appears soon to have been considered as the best, and most practical means for determining initial velocities. Changed and improved, it became in 1858, the standard velocimeter in all military countries, and is the instrument so highly eulogized by General Gibbon. It maintained its supremacy well into the sixties, but is now relegated to museums, from one of which I have exhumed the specimen before you. We have just seen that the swing of a pendulum is a simple and constant time measure at any assumed place. Now, suppose we could start a pendulum swinging at the precise instant when a projectile passed a given point, and stop it again at the precise instant when the

* After the lecture, Major Mordecai informed me that he distinctly recalled Prof. Henry's visiting Washington Arsenal, while the pendulums were erecting, and telling him that the velocity could be determined by electricity.

projectile passed another given point, then knowing the extent of the swing, we would know the time occupied by the ball in passing between the two points, and consequently its velocity, which is the distance divided by the time. This is just what Captain Navez did. He suspended a pendulum by means of an electro-magnet in circuit with one target. The bullet breaks this and the pendulum falls. On the breaking of a second target, the pendulum is stopped by means of another electro-magnet, then thrown into circuit. The pendulum swings in front of a graduated arc, and as it would require a large magnet, and induce severe strains, to attempt to stop it suddenly, a light index needle swings by friction with it, and this is arrested at the proper moment, while the pendulum is free to continue its movement. This would be very simple if the bullet

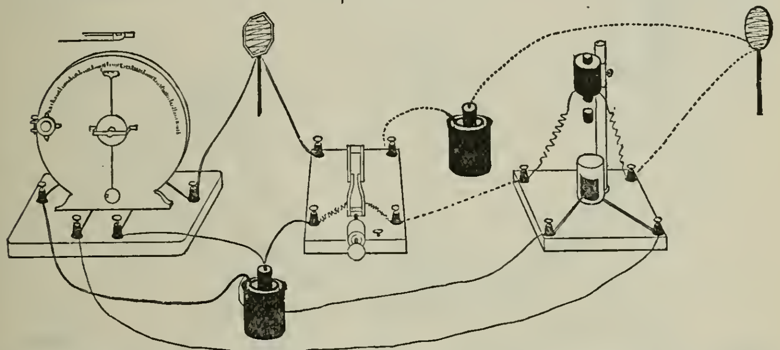


FIG. 11.—Navez's Electro-Ballistic Pendulum, installed with Conjunctor and Disjunctor.

completed a circuit in passing the second target, but it breaks one, and so a rather complicated piece of mechanism, called a conjunctor, also furnished with an electro-magnet, had to be introduced in order to establish the index-needle stopping current, when the bullet broke the target current. We would use an ordinary telegraph relay for this purpose. Now, the electro-magnets and the conjunctor require time for their operation, small in itself but large in proportion to the whole time to be observed, and this instrumental time has nothing whatever to do with the duration of the bullet's flight between the two targets. But it is included in the total recorded swing of the pendulum; we must therefore find out what it amounts to in swing and deduct it in each case from the whole observed oscillation. This is done by means of a disjunctor, an instrument that cuts the circuits of both targets simultaneously.

The swing recorded under these circumstances corresponds to the instrumental time.

Henry's idea of utilizing the induction spark for recording, for which no credit has been given him by European writers, was applied about 1857, by Captain Martin de Brettes, and at about the same time by Captain Vignotti, both of the French army. The latter's instrument is before you ; it is Navez's pendulum combined with Henry's spark. Here the pendulum is sustained by an electro-magnet whose circuit is ruptured by the ball on leaving the muzzle. The pendulum, which is in the secondary circuit of two Ruhmkorff coils connected in series, begins falling,

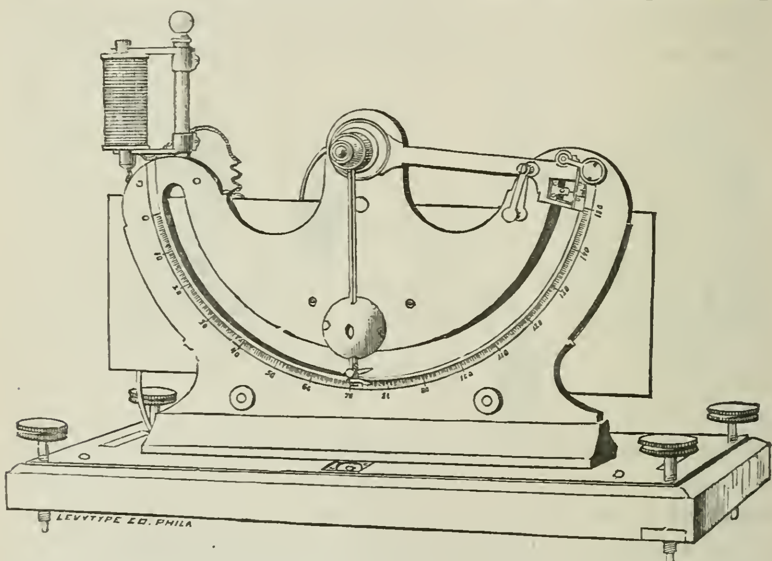


FIG. 12.—Vignotti's Electro-Ballistic Pendulum.

the exact moment is immaterial. The targets are in the primary circuits of the coils ; their rupture causes sparks to pass from the pointer on the pendulum to the metal plate at the back of the slotted arc ; upon this plate is stretched a paper strip dipped in potassium ferro-cyanide, so that the location of the sparks may be evident. The swing between the sparks, as in the Navez, corresponds to the time of the ball. Here we need take no account of the instrumental time, for the determining records are not made until after the pendulum has begun its oscillations.*

* This instrument was greatly improved at the Frankford Arsenal by Colonel Laidley, U. S. A., and Mr. Henry Wernle, the mechanician of the Ordnance Department.

In 1859, Colonel Benton, of our army, to whom, more than any other, is due the development of the present Springfield rifle, designed his electro-ballistic pendulum, a modification and simplification of the Navez machine. Benton used two equal concentric pendulums, suspended by electro-magnets with their "bobs" opposite to each other.

The ruptures of the targets liberated the pendulums successively, and in passing each other the point of meeting was

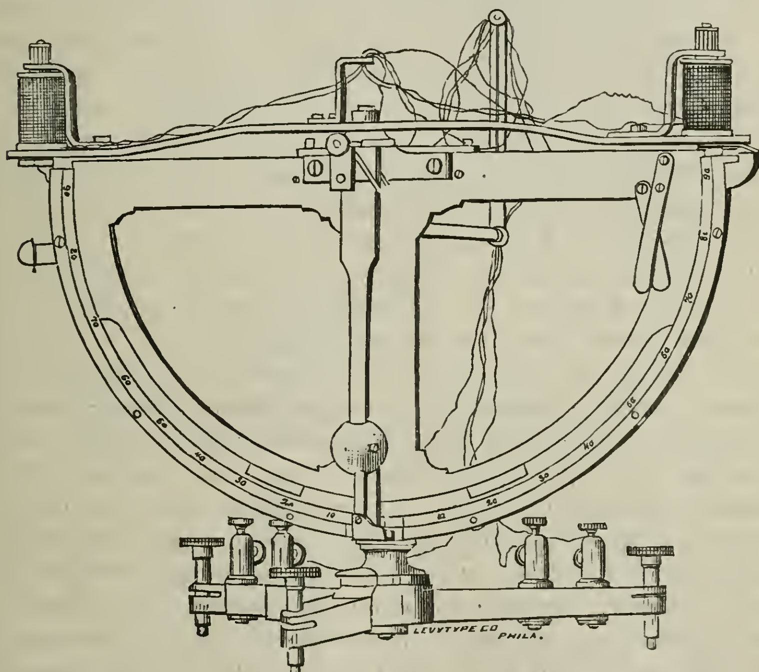


FIG. 13.—Benton's Electro-Ballistic Pendulum.

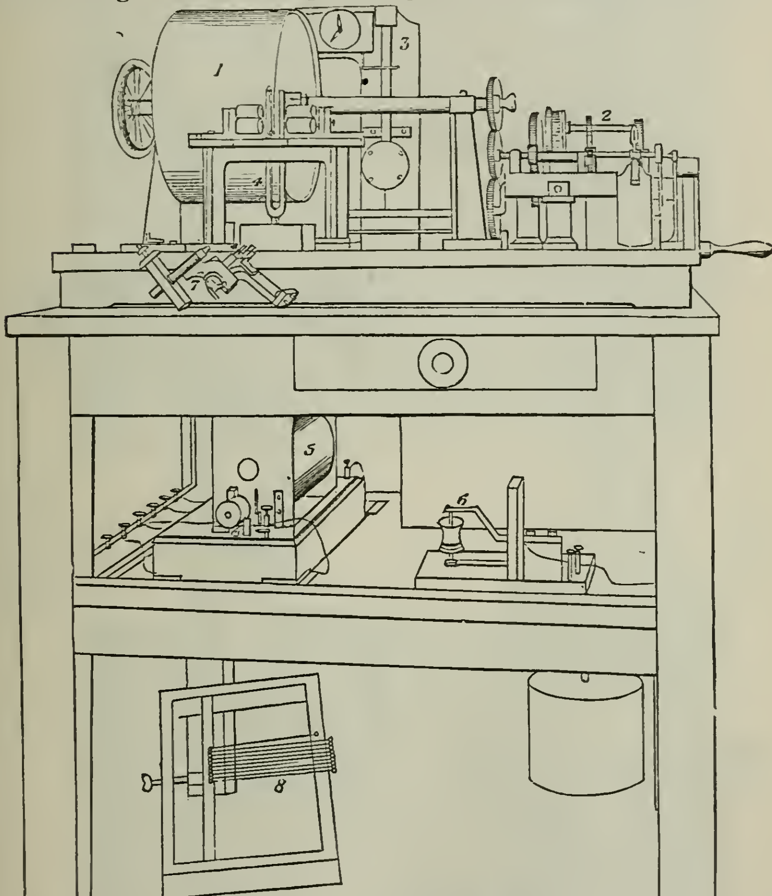
noted on the graduated arc, without interference with the swings. The time sought is the difference between the swings. A disjunctor was required to determine the instrumental time.

This instrument was in general use in this country until about 1874–75. About the close of the war, our Government, upon the recommendation of Colonel Laidley, had fabricated, by Froment, of Paris, a number of Schultz chronoscopes, apparently the limit of continuous electro-micro-chronometry. Captain Schultz, of the French Army, combining Wertheim's method of graphically

recording the vibrations of a tuning fork, Lissajou's and Helmholtz's way of making these vibrations electrically isochronous, and Henry's doubly-moving cylinder and induction spark, produced an apparatus that is capable of meeting every demand of interior and exterior ballistics.

In all previous applications of the cylinder for minute time recording, it was assumed that at least each single complete revolution was made uniformly. This is not true; the rate of even a single turn may vary, and hence equal arcs on the surface may not represent equal times. Schultz reduced the probability of this error to almost nothing, by causing a tuning fork to mark a sinuous line upon the sooted surface of his cylinder during the whole time of its operation. You know that every tuning fork, when vibrating, has its own individual pitch. This simply means that it makes a certain, constant number of vibrations in a second; and as long as the loudness, due acoustically to the size or amplitude of the vibrations, is constant, the fork is absolutely isochronous. If a fork making 500 single vibrations in a second makes its wave-like record upon the moving cylinder, it will in reality divide its surface into 500ths of seconds. Any intermittent change of speed of turning will merely lengthen or shorten these waves, but we know that each, independently of its length, still represents the $\frac{1}{500}$ of a second. Now, while we may with impunity change the length of these waves, it will not do to broaden or to narrow them, for that would indicate a change of amplitude of vibration, a variation in loudness, and therefore a change of time. To keep this amplitude constant, both Lissajous and Helmholtz, by means of electro-magnets, gave a constantly recurring, quick pull, so to speak, to the tines at the moment when they were nearest together, and thus increased the tendency to spread. Schultz uses this method for the same purpose. His interrupter, or device for imparting the electrical "pull" to the tines at the right moment, is a vibrating bar, dipping in and out of a cup of mercury, and requires skill and patience for its proper and continued adjustment. Captain Russell, of the Ordnance Corps, I suppose on the sound republican principle of making "every tub stand on its own bottom," made the tuning fork do its own interrupting, a plan you saw in operation at the Exhibition in the Delaney multiplex and other apparatus. This improvement

greatly facilitated the use of the chronoscope in determining initial velocities. You see now how a very correct time scale may be recorded upon the moving cylinder. Of what avail is this in ascertaining the time of flight of a projectile between two targets?



1. Cylinder. 5. Ruhmkorff Coil.
2. Clock Work. 6. Interrupter.
3. Pendulum. 7. Micrometer.
4. Vibrating Fork. 8. Target.

FIG. 14.—The Schultz Chronoscope.

Imagine the primary circuit of a Ruhmkorff coil to pass through the first target, having for one terminal of its secondary or induced circuit the metallic cylinder, and for the other an insulated point close to its soot-covered surface, and alongside the tuning fork tine that traces the waves.

It is evident that as the bullet ruptures the first target, a spark will pass from point to cylinder, and, burning away the soot, leave

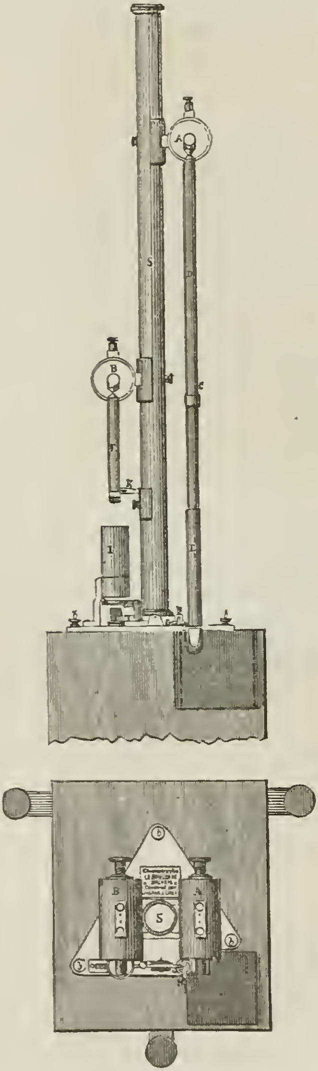


FIG. 15.—The Le Boulengé Chronograph.

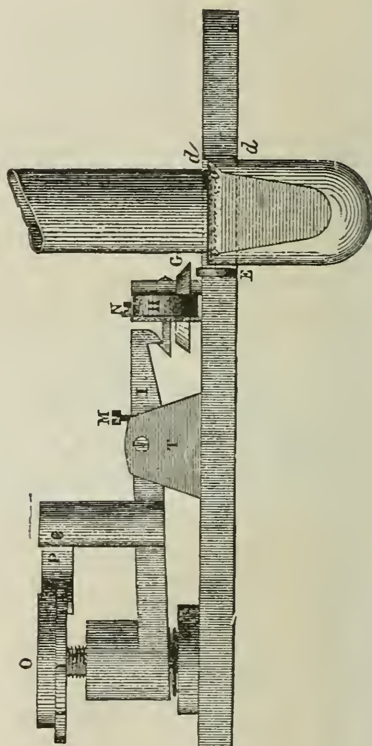


FIG. 16.—Indenter. (Le Boulengé Chronograph.)

exposed the silvered surface below. This, of course, marks the moment of the bullet's passing the first target. If before it

arrives at the second target the primary circuit be re-established, a second spark will again record on the moving cylinder the moment of the bullet's passage. To do this, Schultz made a first target

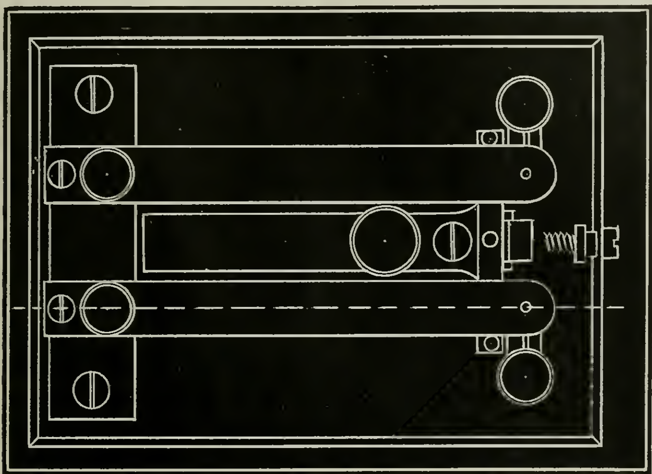


FIG. 17a.—Disjunctor. (Top View.) (Le Boulengé Chronograph.)

very much like a gridiron, each bar or wire bending a spring out of contact with a metal stop. On the breaking of a wire by the bullet, the spring was released, and, in touching the stop, re-estab-

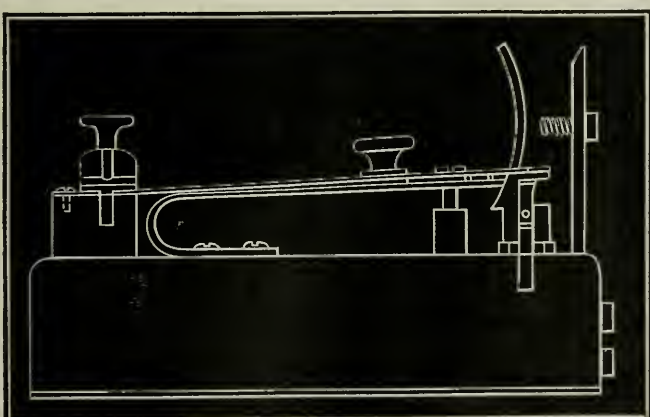


FIG. 17b.—Disjunctor. (Side View.) (Le Boulengé Chronograph.)

lished the primary circuit. With our tendency to get rid of the cumbersome, we threw this aside and substituted the ordinary telegraph relay and other simple devices. Nothing remains but to

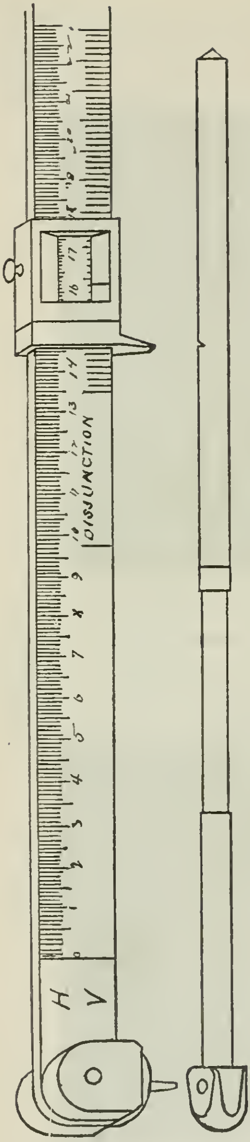


FIG. 18.—Velocity Scale. (Le Boulengé Chronograph.)

count the number of waves and fractions between the two sparks and we have the time and consequently the velocity. A delicate micrometer accompanied the apparatus, by which a wave may be divided into 1,000 parts, each division corresponding to the $\frac{1}{500,000}$ of a second.

In 1863, Colonel Le Boulengé, of the Belgian Army, a most talented officer, devised his chronograph, which, toward 1870, on account of its accuracy, simplicity, portability and cheapness, was adopted in all countries. A falling body is a good time-piece, but it must not be interfered with. In the pendulum, the friction of the axis is a disturbing influence. Le Boulengé got rid of this by reducing the pendulum to its "bob" and allowing it to fall without any restraint whatever, until *after* the record had been made. He suspended a long rod by an electro-magnet, which begins falling upon the rupture of the first target. Upon the rupture of the second target another rod, also suspended by an electro-magnet, drops upon a lever, thereby releasing a spring knife, which, in jutting forward, dents the first rod in its fall. The position of the dent on the rod gives the amount of fall, hence the time, and, as before, the velocity. As with the Navez and Benton machines, an ingenious disjunctor determines the instrumental time. The great practical merit of the instrument lies in the fact that this instrumental mental time can be made *constant*, which permits us to measure off the *velocity* directly from the rod.

This is done as follows: Assume 100 feet between the targets an instrumental error of 0·15 seconds, and an initial velocity of

1,200 feet. Divide the space, 100 feet, by the velocity, 1,200 feet, and we have the time, ·08⅓ second, of passage between the targets; to this add the 0·15 second instrumental time, and we have ·23⅓ second for the time of fall of the rod, corresponding to a distance of ten and one-half inches. Therefore, in our measure, where usually we engrave ten and one-half inches, we would here put 1,200 feet. Of course, it is easy to extend this throughout the whole length of fall. Any one of ordinary intelligence and gentle touch can easily be taught to manipulate the instrument.

And now, in conclusion, I will show you the latest American invention in this department of applied science, a contribution to the Electrical Exhibition, the Cushing velocimeter. We have here the simplest and most constant of all minute time-dividers, an electrically controlled tuning fork, and the Morse recording ribbon sensitized for the galvanic current. Mr. Cushing certainly deserves great credit for thus ingeniously combining two well-known and easily controlled devices, and producing an apparatus, which, while not yet sufficiently accurate for profound scientific research, offers a simple, economical, and correct method for ordinary testing.

In operating the instrument, the paper strip is reeled off by hand; upon it rest three fine iron wires, through the centre one passes the vibratory current, (not Keeley's) that controls the fork, or rather reed, for the fork is reduced to one tine, through the other two, the respective target currents. The centre wire records a continuous dotted line corresponding to the reed's vibrations, the other wires trace straight lines. Upon the rupture of the currents at the targets, these lines are broken. The number of vibrations and fractions recorded between the breaks gives the time. You see that the Cushing velocimeter is the Schultz chronoscope in "shirt sleeves."

To recapitulate, the electric instruments for measuring initial velocities devised up to the present time, may be classified as follows:

Chronoscopes, or direct time-showers.

REPRESENTATIVES.

Wheatstone, Hipp, de Brettes, and others.

Chronographs, or time-writers, subdivided according to the method of recording.

(1.) Upon a timed revolving cylinder—Henry, Konstantinoff, Breguet, Bashfort, Noble, (here the cylinder is divided into parallel discs.)

(2.) Upon a cylinder continuously rotated—Schultz, Cushing, (the cylinder is reduced to a moving strip.)

(3.) By a pendulum—Navez, de Brettes, Vignotti, Benton, Leurs.

(4.) By a freely falling body—Le Boulengé, Watkins.

(5.) By galvanometer deflections—Pouillet, Breguet.

I hope that in this lengthy, sometimes necessarily technical, paper, I have made one thing clear to you, that the application of electricity to the determination of initial velocity has reduced the cumbersome ballistic pendulum, an apparatus, to the simple chrono graph, a tool; that it has done away with all abstruse calculation, and has substituted therefor the method of the foot rule; that it has made it possible for every powder manufacturer to do his own proving. He can now ascertain the velocity of his powder as easily and surely as the apothecary weighs the ingredients of a prescription. He knows what is required—he can produce it, not once, but always. He can make a constant powder, and, as I endeavored to show you in the beginning, upon the uniformity of the powder depends the accuracy of the marksman.

Danger of Electricity from Belts.—M. Boher, the inspector of lighting, in Dresden, has found that the belts even of ordinary steam engines often develop electricity enough to illuminate Geissler tubes and to perform all the ordinary experiments for which electrical machines are used. He thinks that many of the explosions in flouring mills may have been produced by such electricity.—*Cosmos, Sept. 28, 1885.*

Apparent Enlargement of the Sun and Moon when near the Horizon.—Paul Stroobant attributes the apparent enlargement of the heavenly bodies when near the horizon to the combined action of two causes: the first being an apparent reduction of an object in the zenith to about four-fifths of the dimensions of the same object when placed in the horizon; the second being the diminution of brilliancy when the body is rising or setting. The first of these causes appears from Stroobant's experiments to be independent both of the position of the observer's head, and of the apparent flattening of the celestial vault. The question, therefore, is not yet settled, but the observations upon stars at different heights and the experiments with an artificial disc dimly illuminated are ingenious and interesting.—*Bul. de l'Acad. de Belg., No. 8, 1885.*

EXPERIMENTS ON THE TRANSMISSION OF POWER BY GEARING.—MADE BY MESSRS. WILLIAM SELLERS & CO.*

By Wilfred Lewis, Philadelpha, Pa.

[*A Paper read before the American Society of Mechanical Engineers, at the Boston Meeting, 1885.*]

(*Concluded from vol. cxxi, 467.*)

DISCUSSION.

Mr. H. R. Towne.—The relative efficiency of worm and spur gearing has heretofore been largely a matter of speculation and theory, authorities differing widely in regard to it, and no reliable information being given in the text books as to the true efficiency of either under the conditions of ordinary practice. The experiments now under review go further to supply this deficiency than anything previously published, and are of corresponding interest and importance.

The practical value of all such information is increased by stating the results obtained in a summarized form, convenient for reference, and so far condensed as to admit of the whole being comprehended at one time, and with reference to the relationship of each of the several deductions to the others. Such a summary of the experiments presented by Mr. Lewis seems to afford the following deductions and indications:

(1.) That spur gearing is decidedly the most efficient mode of transmitting power by positive gears.

(2.) That the efficiency of a pair of good cut spur wheels, having a velocity ratio of one to three and one-third, ranges from eighty-six to ninety-nine per cent. under average conditions.†

(3.) That with spiral gearing the efficiency is increased with

* From Advance Sheets, Vol. VII, Transactions A. S. M. E.

† Referring to this deduction, Mr. Lewis comments as follows:

"Here I would prefer to see the velocity ratio eliminated, although I recognize it as a variable, which should, strictly speaking, be considered.

"The diagram (*Fig. 99*) is constructed without reference to anything but velocity at the pitch line of teeth, so as not to complicate the question more than is necessary for an approximate determination. As a result of this, I believe that the errors arising from neglecting the velocity ratio, size of

the angle of the thread until the spiral pinion becomes a spur pinion, when the axes of the pinion and its wheel become parallel.

(4.) That with worm gearing the efficiency corresponds at small angles (10° and less) very closely to that of spiral gearing. At greater angles the efficiency of worm gearing does not increase so rapidly as that of spiral gearing, and, unlike the latter, the possible angle of the thread is limited.*

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journals, etc., have a tendency to neutralize each other. For instance, supposing two cases of a wheel and pinion in each of which the same pinion is used. Let the wheel in one case be three times, and in the other six times the diameter of the pinion. For the same velocity of teeth, the pinion in each case makes the same number of revolutions, and the friction on its journals is the same. The smaller wheel, however, runs twice as fast as the larger, and there is consequently twice as much sliding in the journals in its case; but, on the other hand, the coefficient of friction for the smaller wheel is much less on account of higher velocity.

"By the same reasoning large journals would compensate partially, in the reduction of the coefficient of friction, for the increase in the amount of sliding. This feature is not proved, of course, but such a tendency, no doubt, exists, and is further augmented by the fact that, in general, the larger the wheel, the larger are its journals. It may be stated, as a general principle, that the higher the number of teeth gearing together and the smaller the journals, consistent with strength and stiffness, the greater the efficiency.

"The limits imposed upon all proportions of gearing by considerations other than that of efficiency do not, I think, admit of such great variations as to require in ordinary practice a consideration of the question of velocity ratio. Taking any pair of shafts connected by gearing, I think it will be admitted that the efficiency will increase with an increase in the size of either one of the gears, whether the velocity ratio becomes greater or less. I would suggest, therefore, that as the velocity ratio cannot be used as a guide or limit, it may properly be omitted from the statement covered by your second deduction from the experiments reported by me."

* On this latter point, Mr. Lewis suggests as follows:

"The limiting angle for the maximum efficiency of worm gearing is to be determined in a manner similar to that for screws, as fully explained in a paper which I prepared some years ago, and which may be found at page 73 of THE JOURNAL OF THE FRANKLIN INSTITUTE for February, 1880. The formula particularly referred to is No. 6, on page 76, from which it will be seen that the angle for greatest efficiency is probably limited to something approximating to 45°. Although this angle has been often used on screws with good results, I should hesitate to recommend it for worms on account of the heavy side thrust upon the worm wheel, and I am inclined to think that 30° is the more nearly correct figure for the limit for maximum efficiency of worms."

(5.) That the efficiency of spiral and worm gearing (of cast iron, machine-cut or worn smooth) ranges from thirty-five to ninety per cent., according to the conditions of speed, angle, pressure and quality of surfaces.

(6.) That with each kind of gears there exists a certain point of maximum efficiency, depending chiefly, under average conditions, upon the velocity of the rubbing surfaces.

(7.) That very high velocities develop a tendency of the rubbing surfaces to cut, and that this difficulty then becomes a limiting condition.

(8.) That with worm gearing, a large part of the applied power being lost in end-thrust on the worm shaft, it becomes correspondingly important to adopt a form of end-bearing which will diminish this loss as much as possible.

(9.) That the range of variation from the mean line of efficiency in the Sellers experiments rarely exceeds five per cent. in either direction, in the case of worm gearing, and is diminished to about three per cent. in the case of worms of high angles and spur gearing, so long as no cutting occurred, but that the variation became much greater and very irregular as soon as cutting began.

(10.) That in general, at slow speeds, the greatest efficiency is found under the heaviest pressures; at moderate speeds, under moderate pressures; and at high speeds, under light pressures. This seems to indicate a limiting point for the product of speed and pressure at which the heat of friction is so rapidly developed as to impair either the condition of the surfaces in contact, or their lubrication, and cause cutting.

(11.) That the liability to cutting depends upon the speed of sliding, being also affected by the quality of lubrication, the intensity of pressure, and the period of duration.

(12.) That with worms and spiral gears, time or duration of action is a limiting element, a good pair of gears being capable of efficient action for five or ten minutes, or more, but failure from cutting will result after the proper time is exceeded. (See table on page 453, vol. cxxi, J. F. I.)

(13.) That the maximum efficiency is attained at or below a velocity of 300 feet per minute of the sliding or rubbing surfaces, and that while it is possible to exceed this limit temporarily with good results, it is somewhat hazardous to do so. For continuous

work 200 feet per minute is probably the highest velocity of rubbing surfaces which can safely be adopted without danger of cutting.

(14.) That in spur gearing the chief loss from friction is in the journals, which should therefore be carefully designed; that the same is true in the case of worm gearing, but that it is still more important in the latter to provide for the reduction of friction due to the end-thrust on the worm shaft.

(15.) That the coefficient of friction (φ) of the spiral pinion and the worm, including step friction, ranges from two to nine and one-half per cent. (See table on page 463, vol. cxxi, J. F. I.)

The importance of the above determinations admits of no question, and will be apparent to any one who has ever given consideration to the subject to which they relate. The application of them, and of their summarized results, as shown in the tables on pages 453 and 463, and in the diagrams of efficiency (*Fig. 99*), will be of the greatest service in adapting gears of any kind to any particular use, and this is especially true in the case of worm gearing—wherein heretofore the limiting conditions have been but little understood.

As a further contribution on this subject, I will now describe the results obtained from a series of experiments made at the instance of the writer, for the Yale & Towne Manufacturing Company, by Professor R. H. Thurston, at Stevens Institute of Technology, in 1883–84.

In this case the gears experimented with consisted of a cast iron worm wheel of $15\frac{15}{16}$ inch pitch diameter, with 50 machine-cut teeth, $2\frac{1}{2}$ inch face; driven by a double-threaded cast iron worm, machine-finished, 6·1 inch pitch diameter, and 4 inches long on the thread. The velocity ratio was twenty-five to one. These gears were set in a suitable frame, and were driven by power transmitted by shafting and belting through a transmitting dynamometer, carefully standardized. The power transmitted from the gearing was taken off and measured by a Prony brake, also carefully adjusted. The tests were made with much care, and by competent observers, and were sufficiently numerous to give assurance of reliable results. The range of speeds covered by the experiments extended from forty-one to 339 revolutions of the worm per minute, and the variations in the amount of power transmitted

to the gearing ranged from ·2 to 4·14 horse-power. In each case, apparently, the experiments were carried up to and beyond the point of maximum efficiency, which latter was, of course, the determination aimed at in the investigation. The range of speeds above referred to gave velocities of the rubbing surfaces ranging from sixty-five to 538 feet per minute. The latter speed afforded clear indications that the point of maximum efficiency had been reached and passed, its location, under the conditions of the tests, being apparently at or about the point of 243 feet per minute of the rubbing surfaces (which is obtained at a speed of 140 revolutions of the worm per minute), a result strikingly corroborative of the work of Mr. Lewis.

Appended hereto are two tables, No. 1 giving the dynamometer readings, speeds and efficiency of the gears under varying conditions, and No. 2 showing a summary of the same, with the coefficient of friction as deduced therefrom.

By examining these tables, it will be seen that the ratio of power absorbed or lost in the gearing decreases with increasing velocity up to a maximum at the point where the velocity of the rubbing surfaces is 243 feet per minute. As the speed is further increased a decrease in efficiency occurs, thus indicating clearly the speed at which the gears experimented with, should be driven, in order to attain the highest efficiency in amount of power transmitted. Obviously the precise velocity of maximum effect will vary with the degree of pressure on the rubbing surfaces, and also, to a less extent, with the kind of lubricant used. In the present case the maximum obtained was with the highest pressure consistent with the general strength and rigidity of the apparatus, and with thorough lubrication with good sperm oil. It thus represents conditions which are probably the best ordinarily attainable, and the maximum efficiency thus indicated, while closely approachable, will rarely if ever, be exceeded in ordinary practice.

The results of the tests made by Professor Thurston, as above described, showed a lower efficiency of transmission from the gears than was expected, and this led to an investigation as to the causes of loss. Chief among the latter was evidently the absorption of power caused by friction due to the end-thrust of the worm against its bearing in the frame. To diminish the loss from this cause, the apparatus was thereupon provided with two forms of

thrust-bearing for the worm-shaft, so arranged that either could be readily applied and tested independently of the other.

As originally constructed, the end-thrust of the worm was taken directly from its hub upon a corresponding face or collar of the cast-iron box contained in the frame or housing, the width of this surface of contact being one inch, and its mean radius from the centre of the shaft or worm one and one-fourth inches. The two modified arrangements consisted:

(1.) Of what is usually known as the "button thrust-bearing, or step, in which the projecting end of the worm shaft is capped with a thin disc of hardened steel, the exposed face of which is slightly convex, and behind this is placed an adjusting set screw, with its hardened end abutting against the disc on the end of the shaft. In this case, the area of contact of the rubbing surfaces is the minimum which, with the metals used, will resist crushing under the thrust received. The radius of rotation is obviously also reduced to a minimum, and is very small. The whole bearing was kept well oiled.

(2.) Of an adaptation of the well-known roller thrust-bearing, consisting, in this case, of twelve chilled cast-iron coned rollers of nine-sixteenth inch mean diameter, contained within a brass cage having a separate pocket for each cone, the cones travelling, at a mean radius of one and three-eighths inches from the axis of the shaft, between two steel collars, or rings, one bearing against the hub of the worm, and the other against the face of the frame bearing, the faces of these rings being coned to the shape of the rollers. The centrifugal thrust of the cones was resisted by a wrought-iron ring surrounding the cage, the ends of the cones being convex.

The apparatus being thus modified, further tests were made, the results of which, in the case of the button thrust-bearing, are shown by Table No. 3, and in the case of the roller thrust-bearing by Table No. 4. A comparison of these with the preceding tables at once discloses the fact that the efficiency of the gearing is materially increased by both forms of thrust-bearing, a maximum of over sixty per cent. being obtained with the roller thrust-bearing, as compared with a maximum of forty-three per cent. with the original bearing. The efficiency of the improved apparatus is thus fifty per cent. greater than that of the original

arrangement, showing conclusively that a well-designed thrust-bearing is a most important feature in worm gearing for the transmission of power. Appended to this are diagramatic plottings of the several tests above described (*Figs. 137* and *138*), an examination of which will show a curious divergence in the curve of efficiency of the button, and of the roller thrust-bearings. This discrepancy, or divergence, led to some apprehension of an error in the tests, and to remove doubt on this point the experiments were repeated, but with no change in the results. It is probable, therefore, that under high pressures the roller bearing is subject to deformation, or other alteration from strain, which decreases its

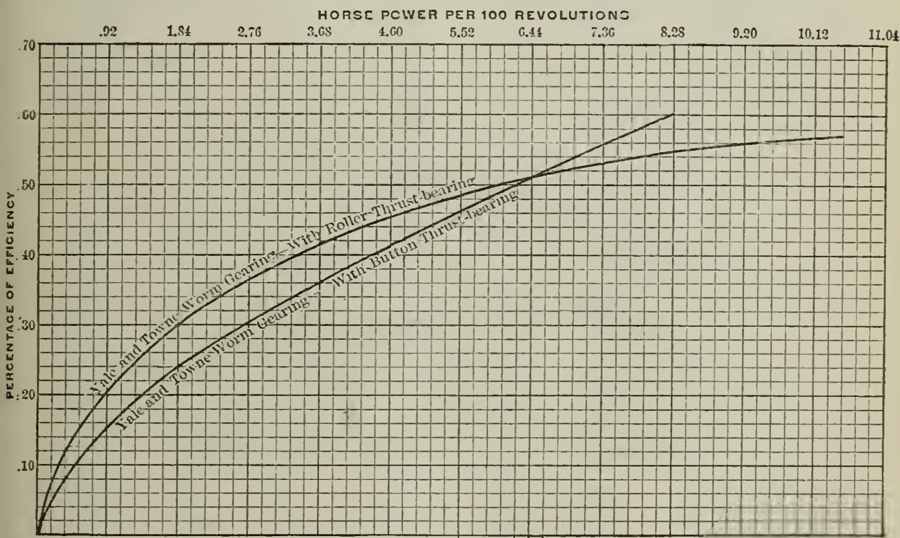

FIG. 137

efficiency, whereas the button bearing continues to gain in efficiency up to the point where cutting of the surfaces will begin. The general results of Professor Thurston's tests, as above referred to, are very clearly exhibited in the above diagrams, *Figs. 137* and *138*.

The results of the tests thus reported are strikingly confirmative of those made by Mr. Lewis, and all of the deductions which I have stated as to be derived from his work, apply almost equally to that of Professor Thurston. The chief importance of the latter, aside from its general confirmation of the former, is the clear indication it gives of the importance of providing for the end-thrust of

the worm much more carefully than has ordinarily been done. The experiments show that by a very simple provision of this kind the efficiency of the worm can be increased fifty per cent. Thus constructed, its absolute efficiency may be said to range from fifty per cent. to sixty per cent. of the power received, as compared to an efficiency of seventy-five per cent. to ninety-five per cent. in the case of the best cut spur gearing. Worm gearing thus becomes a permissible mode of transmitting power in many cases where a large velocity ratio is desired within a small space, where it is necessary to connect two shafts whose axes are at right angles, and especially where the duty on the gearing is intermittent and the duration of maximum stress limited to short periods of time. On the other hand, it is obvious that worm gearing cannot, under

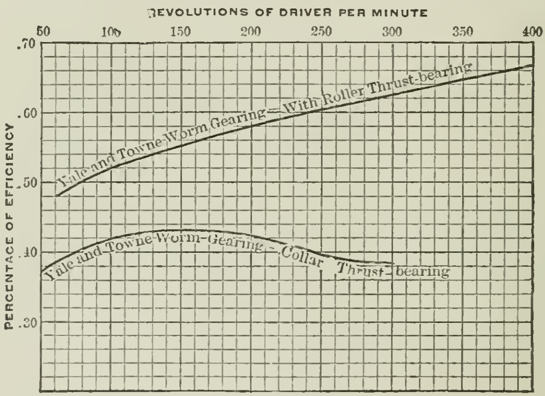

FIG. 133

any circumstances or conditions, be as efficient a means of transmitting power as well-made spur gearing, and that the loss of efficiency becomes very excessive when worm gearing is used at slow speeds. *These facts indicate clearly, therefore, that the use of worm gearing for transmitting power in machines moved by manual labor, and at slow speeds, should always be avoided, if possible.* In machines driven by steam, or other power, worm gearing is often a most convenient and useful substitute for spur gears, and, if properly designed and used, is not so much below the latter in efficiency as to cause any hesitancy in its employment. The proper methods of constructing and using worm gearing will certainly be better understood by a study of the investigations reported in the preceding pages.

TABLE No. 1.

YALE AND TOWNE WORM GEARING. WITH COLLAR THRUST-BEARING.

Reading on Dyn.	Rev's. of Dyn.	Rev's. of Worm.	Rev's. of Gear.	Pounds on 4 foot Arm.	Horse-power Received.	Horse-power given out.	Effic.
½	70	50·7	2·03	59	·252	·0914	·362
1	70	50·7	2·03	116	·417	·176	·422
1½	72	52·1	2·08	160	·599	·254	·424
2	70	50·7	2 03	213	·747	·33	·441
2½	66	47·8	1·91	250	·860	·264	·423
3	67	48·5	1 94	290	1 032	·429	·415
½	57	41·6	1·23	58	·205	·055	·268
½	108	78·6	3·14	61	·388	·146	·376
½	135	97·8	3·91	65	·486	·194	·399
1	54	39·1	1·56	92	·322	·109	·338
1	97	70·6	2·82	100	·578	·215	·371
1	122	88·7	3·54	106	·727	·286	·393
2½	157	116·	4·64	252	2·04	·892	·437
2	157	116·	4·64	212	1·67	·751	·449
1½	162	119·	4·76	157	1·34	·570	·425
1	168	123·	4·92	105	·995	·39	·391
1	162	117·7	4·7	119	·965	·427	·444
½	159	115·5	4·62	68	·572	·239	·417
1	197	143·1	5·72	121	1·174	·528	·449
½	212	153·9	6·15	71	·763	·333	·436
1	255	184·	7·36	123	1·519	·691	·454
½	285	206·5	8·26	69	1·026	·435	·423
¾	218	165·	6·64	91	1·04	·460	·435
¾	266	195·	7·80	87	1·27	·517	·417
½	285	206·	8·26	69	1·026	·435	·423
1½	333	243·	9·72	143	2·76	1·09	·395
1⅜	370	281·	11·24	155	3·26	1·36	·417
1¾	365	266·	10·64	167	3·03	1·221	·403
1⅞	395	283·	11·32	182	3·51	1·61	·458
1¼	393	280·	11·20	120	2·81	1·05	·373
1	318	233·	9·32	115	1·90	·85	·447
1¼	318	233·	9·32	134	2·27	·985	·434
1	308	225·	9·00	101	1·83	·717	·392
1	400	294·	11·76	98	2·38	·912	·383
¾	304	274·	10·96	85	1·79	·732	·409
1¼	464	339·	13·56	119	3·31	1·27	·384
1½	413	303·	12·12	139	3·44	1·33	·386
1⅝	465	337·	13·48	168	4·14	1·77	·427
1 9/16	442	323·	12·92	152	3·58	1·52	·424
1½	453	331·	13·24	137	2·77	1·41	·375
1½	434	317·	12·68	130	3·61	1·3	·36
1	400	294·	11·76	98	2·38	·91	·382
1	436	826·	13·04	96	2·60	1·03	·396
⅝	439	320·	12·80	70	1·81	·72	·398

TABLE No. 2.

YALE AND TOWNE WORM GEARING. WITH COLLAR THRUST-BEARING.

Revolutions of Worm.	Velocity of Rubbing.	Horse-Power Received.	Efficiency.	Coefficient of Friction.
45·5	72·	·229	·347	·194
84·	132·8	·545	·383	·162
88·7	140·3	·727	·393	·159
118·	186·6	1·51	·425	·140
154·	243·6	·993	·440	·132
195·	308·5	1·27	·431	·136
226·	357·5	1·957	·418	·144
275·	435·	2·81	·405	·152
285·	450·8	2·83	·402	·154
315·	498 3	2·96	·390	·160
333·	526·8	3·45	·395	·158

TABLE NO. 3.

YALE AND TOWNE WORM GEARING. WITH BUTTON THRUST-BEARING.

Net W't in Pounds on Scale.	Rev's. of Worm.	Rev's. of Gear.	Reading of Dynam.	Rev's. of Dynam.	Horse-Power as per Dynam.	Horse-Power as per Brake.	Efficiency.
1·20	128·	5 12	·030	179·	·247	·005	·020
1·25	175·	7·00	·010	242·	·311	·008	·024
10·80	136·	5·44	·092	188·3	·315	·054	·170
10·80	128·	5·12	·030	180·	·248	·058	·234*
16·52	165·	6·60	·181	225·3	·472	·100	·212
16·54	196·	7·84	·240	268·3	·636	·119	·171*
17·35	140·	5·60	·203	192·3	·423	·092	·217
18·09	98·	3·92	·204	134·	·295	·068	·230
19·94	32·	1·28	·226	44·7	·103	·023	·223
36·50	356·	14·24	·393	462·7	1·432	·478	·334
37·66	175·	7·00	·377	234·	·706	·240	·339
39·06	310·	12·4	·443	63·	1·470	·444	·302*
39·07	136·	5·44	·355	188·3	·549	·190	·346
39·25	103·7	4·188	·338	141·7	·402	·150	·373
42·61	108·3	4·33	·407	148·3	·468	·170	·363
42·96	34·7	1·388	·214	47·	·106	·054	·509*
43·22	46·3	1·85	·443	63·	·210	·076	·361
49·55	176·	7·04	·280	242·	·619	·290	·471*
55·40	196·	7·84	·434	268·3	·882	·390	·442
64·18	128·3	5·08	·467	175·	·602	·299	·496
84·77	129·	5·16	·562	181·7	·707	·402	·568

* Doubtful.

TABLE No. 4.

YALE AND TOWNE WORM GEARING. WITH ROLLER THRUST-BEARING.

Net W't in Pounds on Scale.	Rev's. of Worm.	Rev's. of Gear.	Reading of Dynam.	Rev's of Dynam.	Horse-Power as per Dynam.	Horse-Power as per Brake.	Efficiency.
20·50	168	6·72	·123	231	·2404	·1267	·301
36·92	155	6·20	·265	214	·5328	·2105	·395
37·25	168	6·72	·255	231	·5645	·2302	·408
41·21	100	4·00	·324	138	·3820	·1516	·397
43·08	170	6·80	·310	233	·631	·2695	·427
49·40	170	6·80	·347	233	·6705	·3089	·460
49·89	197	7·88	·365	279	·826	·3616	·438
52·70	214	8·56	·459	297	1·011	·4149	·410
55·07	139	5·56	·433	194	·537	·2876	·535*
58·88	85	3·40	·503	118	·426	·1841	·432
60·23	182	7·28	·452	253	·8534	·4039	·473
65·36	319	12 76	·459	441	1·502	·764	·509
65·72	168	6·72	·503	231	·8348	·4061	·486
65·90	168	6·72	·507	231	·8410	·4069	·484
68·06	174	6·96	·491	238	·8466	·4386	·518
105·00	121	4·84	·869	167	·892	·4673	·524
110·59	320	12·80	·936	442	2·500	1·6048	·642*
115 07	156	6·24	·891	215	1·171	·6603	·5644
115·34	354	14·60	·793	488	2·509	1·5019	·598
119·26	260	10·40	·853	359	1·8905	1·1406	·603
121·48	217	8 68	·912	299	1·6578	·9666	·583

* Doubtful.

VIOLENT STORM.—During a violent storm at Torre-Cajetani, thirty-six frightened peasants took refuge in a house which was struck three times by lightning. Thirteen of them were killed, and the others were all wounded more or less severely.—*Cosmos, Aug. 10, 1885.*

DANGER FROM UMBRELLAS AT SEA.—In these days of electric lighting, one is often in the neighborhood of dynamos, and, however short the time of exposure to their influence, pocket knives and the steel in watches and umbrella frames may become powerfully magnetized. On board the *Princess Beatrice*, the helmsman lately observed that the compass was agitated. On examination, he found that the needle was affected by the magnetized steel mounting of a parasol in the hands of a lady who was walking upon the bridge. If the lady had been at rest, so that nothing would have shown the abnormal deviation, the ship might easily have been steered out of its course and thus been exposed to dangerous accidents.—*Cosmos, Oct. 12, 1885.*

The MICROSCOPIC STRUCTURE of CAR WHEEL IRON.

By F. Lynwood Garrison, F.G.S.

[*Read at the Pittsburgh Meeting of the American Institute of Mining Engineers,* February, 1886.*]

The study of the microscopic structure of the iron of car wheels, which it is the aim of this paper to describe, was made at the suggestion of Dr. Dudley, whose paper upon the constitution of cast irons precedes, and should be read in connection with, this one. Although the two wheels referred to in that paper possess nearly an identical ultimate chemical composition, they possess, as Messrs. Dudley and Pease have shown, physical properties so widely different, as to make one of them nearly worthless for the purpose for which it was cast. Considering the chemical similarity, such a marked difference in strength cannot but be very striking, and goes to show how little reliance can be placed upon chemical analysis alone, if *not properly interpreted.* I say "not properly interpreted," because I believe that very few analyses of iron or steel are thus fairly dealt with. That an analysis may read so much of one thing and so much of another, tells us very little as to the properties of the metal; for these are determined to a large extent by the conditions and relations in which the elements are present. To the unaided eye the difference between the two wheels under consideration is not striking. The inferior one would be described as light gray, and the other as somewhat darker. Upon careful examination of an etched fragment, however, the difference in structure will be found to be very marked, as may be seen in *Figs. 1* and *2* (produced from photographs by the Ives process).

It is exceedingly difficult to produce a photograph giving a fair notion of the appearance of the metal under the microscope, so as to give to persons not familiar with microscopical study, a proper appreciation of what a microscopist would consider a decided difference in structure. I would, therefore, urge any one especially interested in this subject, not to depend upon the photographs of

* From advance sheets of the *Trans. A. I. M. E.*

others, but to prepare and etch the specimens himself, and then examine them with a good microscope.

As is well known, iron possesses the property of uniting with a number of elements, forming products which are either highly intimate mixtures of several substances, or else compounds of an indefinite character. Indeed, such mixtures may be regarded as alloys, or as Matthiessen puts it, "solidified solutions of one substance in another." Of all the elements commonly associated with iron, carbon and, possibly, silicon have the peculiar property of being capable of existing in the compound in two distinct conditions, one in an amorphous or combined state, and the other as graphite in mechanical mixture with the iron. From the recent researches of Sir Frederick A. Abel,* Dr. C. B. Dudley, and F. N. Pease, of Altoona, Pa., there seems to be much to strengthen the belief of the existence of carbon in iron in a third and combined form, as a "carbide of iron." This compound is described as a "definite product capable of resisting the oxidizing effect of an agent which exerts a rapid solvent action upon the iron through which this carbide is distributed. It is gray in color, and seems to exist in small granules, affecting the continuity of the metal."

That such a compound of carbon and iron exists as such in the metal, is by no means proved; and so far as the writer's researches with the microscope have extended, there seems to be little evidence for or against such a hypothesis. It is a generally accepted belief that, when present in considerable quantity, graphitic carbon has a decided effect in decreasing the strength of cast iron. Such is certainly the case when a certain limit has been passed; but just what this limit is, it would be difficult to determine. It is very probable, however, that this limit is affected by the amounts of other elements present, and by the conditions under which the metal has been fused and cooled, or treated at a temperature below its melting point. Thus it is found that hardened steel yields no sensible residue of graphite when dissolved in acids; but if, on the other hand, the same steel be annealed, a very considerable amount of graphitic residue will be obtained. It also seems that a temperature much higher than that of the melting point of the metal is necessary to produce graphitic

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* *Journal of the Iron and Steel Institute.*

iron, and that slow solidification after fusion is the condition most favorable to the separation of the graphite in flakes or laminæ. On the other hand, rapid solidification or chilling favors the retention of the carbon in the combined or amorphous state, and produces a hard, white, and highly crystalline iron, melting at a temperature considerably lower than gray iron. When the amount of manganese present is relatively large, the separation of graphitic carbon takes place to but barely an appreciable extent, the resulting mass, after fusion and solidification, being highly crystalline, and with fractured surfaces of great brilliancy, whence the name of spiegeleisen.

It seems almost certain that there exists no ordinary iron or steel in which *all* the carbon is contained in either one condition or the other, but that it always exists in the two (or three) conditions together, and that upon the relative proportions of these depends, in great degree, the quality of the metal. Thus in cast iron, if the relative amount of combined carbon is large, we have a white iron, but if small, a gray graphitic iron with quite different physical properties. Car wheels being made usually from the best grades of pig iron can be described as gray iron, the periphery or "tread" alone being white or chilled, and, of course, between the two, a small intermediate zone, containing varying proportions of combined and graphite carbon. In nearly all varieties of gray cast iron, a very marked and characteristic development of the graphitic carbon will be observed when a fragment of the metal has been carefully ground, etched, and microscopically examined. As will be shown below, the existence of the graphite in strong and well-defined lines and plates has a most important bearing upon the strength of the metal.

In *Fig. 1*, taken from a photograph showing the microscopic structure of the good car wheel iron, the plates and lines of graphite are very marked, and appear as an irregular mass of small black lines, which might be likened to a number of small black worms wriggling and squirming throughout the metal. The surrounding mass of metal presents a compact, granular, non-crystalline structure, frequently containing cavities, due to occluded gases or air. It seems impossible to produce castings altogether free from these defects—and it does not need always the microscope, or even a magnifying glass, to detect them—but it is doubtful

FIG. 1.—Good Car-wheel Iron.

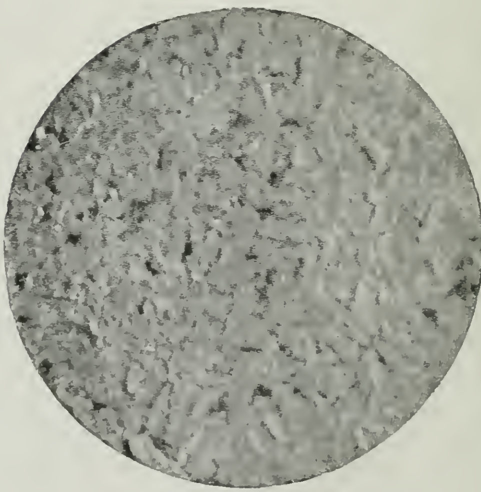


FIG. 2 —Poor Car-wheel Iron.

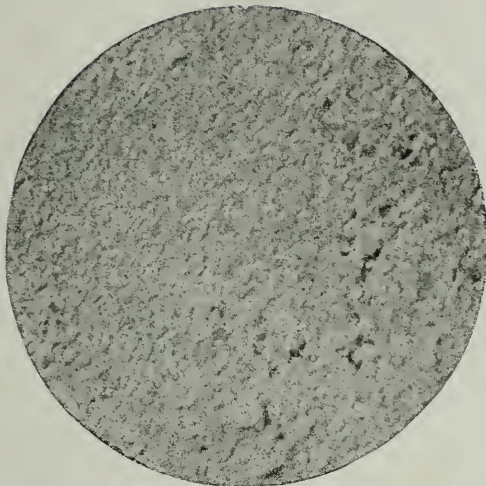


Fig. 3.—Weak Pig Iron.

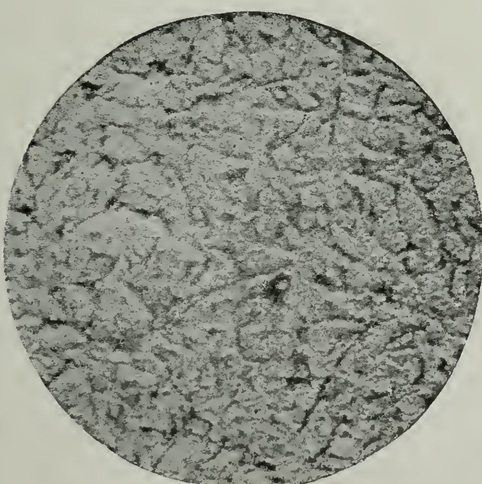


Fig. 4.—Hot-Blast Charcoal Iron.

whether their absence would prove of much benefit to the metal for practical purposes. On further examination of *Fig. 1*, it will be observed that very little of the graphite occurs in isolated irregular patches, as will be seen to be almost always the case in the poorer grades of cast iron.

In *Fig. 2*, we have the structure of the poor car wheel iron. It will be noticed that, although the mass of the metal itself appears to be the same as that of the good wheel, the well-developed and prominent graphite plates are absent, and are replaced by the graphite in irregular and somewhat isolated patches of comparatively large size, and without any regular grouping. This peculiarity seems general, and characteristic of the poorer grades of cast iron. In nearly all cases metal which shows it is unreliable, lacking the toughness and durability of the better grades.

In *Fig. 3*, is exhibited a similar structure, being that of a weak and almost valueless pig iron, containing 4·6 per cent. of carbon, 3·22 per cent. of which is present as graphite in irregular patches, as in *Fig. 2*, the metal mass itself being compact and granular.

In *Fig. 4*, is shown the structure of a high grade hot blast charcoal pig iron ; the similarity of its structure with that of the good wheel is quite apparent, except that in the latter the graphite plates are somewhat larger and more prominent.

These facts indicate that the development and distribution in well-defined lines or plates of the graphite carbon is at least as important a factor of quality, up to a certain limit, as its total amount. Although it is generally supposed (and undoubtedly with good reason, when the limit has been passed) that the presence of graphite in quantity renders the metal weak, I have found, in almost all cases where the iron lacked strength, that the development of the graphite in plates was only incipient, and that the graphite present existed in irregular patches or clusters of great variety in size and shape.

Of course, this connection between the strength of the metal and the form and distribution of its graphitic contents, even if proved to be an invariable one, need not necessarily represent the only, or the whole, explanation of the case of the two car wheels now under consideration. Nor is the question answered, to what cause the difference in graphite distribution is due. Perhaps the following facts may throw some light upon the problem.

Percy* says, that the mode of existence of the carbon in iron and steel is, to a certain degree, determined by the conditions under which the solid metal has been heated and cooled at temperatures very much below its melting point. This point is best illustrated by the annealing of hard steel, and its subsequent treatment with acids, before alluded to. Again, according to Karsten, it seems that even if cast iron is allowed to cool with the utmost slowness after fusion, it is not then converted into gray iron unless it has been melted at a much higher temperature than was required to bring it to a liquid state.

The following are the analyses of the two wheels, as given by Messrs. Dudley and Pease:

	Good Wheel.	*Poor Wheel.*
Total carbon,	3·84 per cent.	3·53 per cent.
Graphite,	3·30 "	2·36 "
Combined carbon,	0·54 "	1·17 "
Silicon,	0·69 "	0·65 "
Phosphorous,	0·43 "	0·52 "
Manganese,	0·13 "	0·12 "
Sulphur,	0·12 "	0·19 "

From these analyses, it will be observed that the poor wheel contains 0·07 per cent. more sulphur than the other. Bell,† in speaking of the influence of sulphur upon cast iron, observes that, "speaking in general terms, it seems probable that the presence of this element interferes, in some way, with the separation of carbon in the graphitic state, a condition which appears essential to the formation of soft iron."

Although it may not apply in this particular case, it is a well-known fact that silicon, when present in considerable quantity, seems to favor the separation of graphitic carbon, and that the grayest iron is apt to be the richest in that element. As will be seen from Dr. Dudley's paper, the small difference in the amounts of phosphorus present in each wheel, does not, in all probability, affect the result, so that its presence need hardly be considered.

The above citations point to the conditions of fusing and cooling, and to the relative proportions of ingredients other than carbon, as controlling the separation of graphite. Dr. T. M. Drown‡

* *Metallurgy of Iron and Steel.*

† *Principles of the Manufacture of Iron and Steel*, p. 103.

‡ *Transactions*, vol. viii, p. 41.

has suggested a very beautiful hypothesis, according to which the amount of graphite separated in any given instance is proportional to the time consumed by the pig iron in passing through a limited range of temperature, probably near the point of solidification. Adopting this hypothesis, may we not further imagine that the other ingredients, affecting the melting point of the compound, affect also the limits of this range of temperature; but that, these things being equal (as they almost are in the case before us), the conditions of casting and cooling may decide the quality of the product, by determining not merely, as Dr. Drown suggests, the amount, but also the form and distribution of the segregated graphite?

THE REFRIGERATION MACHINE AS A HEATER.

BY GEORGE RICHMOND.

Although the isentropic transfer of heat is usually impossible, yet we can approach as nearly to it as we desire, and the results based on the assumption of sources of heat of unlimited extent can be realized as nearly as practical construction can bring us to the limiting condition. Thus if we have an infinite supply of heat at T^0 we can transfer a finite quantity at T^1 very near to T^0 without sensible increase of entropy, and the practical limit of such a process is only reached when the value of the energy saved from dissipation is less than that required by the mechanism to effect the contact. On this understanding, the following discussion considers only the limiting case.

Suppose we have a quantity of heat Q_1 at temperature T_1 (absolute). By simple transfer (using the ordinary irreversible processes of conduction or radiation) to a lower temperature T_2 the quantity of heat remains unchanged, but the entropy is increased.

$$Q_1\left(\frac{1}{T_2}-\frac{1}{T_1}\right) \qquad (1)$$

and the available energy between T_1 and T_2 is entirely dissipated.

But if this heat Q_1 is passed through a heat engine in accordance with the second law of heat, we have an isentropic transfer of heat to T_2, amounting to

$$Q_1 \frac{T_2}{T_1} \tag{2}$$

and a quantity of work, of which the heat equivalent is

$$\frac{Q_1}{T_1}\left(T_1 - T_2 \right) \tag{3}$$

Suppose T_3 (lower than T_2) the temperature of surrounding object or the *highest* unlimited source of heat available for a reversed heat engine, and let the work (3) be employed in such an engine to effect a transfer of heat from T_3 to T_2, the amount thus transferred is

$$\frac{Q_1}{T_1}\left(T_1 - T_2 \right)\frac{T_2}{T_2 - T_3} \tag{4}$$

We have, therefore, at T_2 an amount of heat represented by the sum of (2) and (4), or

$$Q_1 \frac{T_2}{T_1} \left(\frac{T_1 - T_3}{T_2 - T_3}\right) \tag{5}$$

which is always greater than Q_1, the original amount of heat employed. The relative effect of the mutual relation of temperature is more clearly seen by putting (5) in the equivalent form

$$Q_1 \frac{T_2}{T_2 - T_3} \left(1 - \frac{T_3}{T_1}\right) \tag{6}$$

from which we see that the transferred heat rapidly increases, as T_2 is more nearly T_3, and also increases but less rapidly as T_1 is removed from T_3. Moreover, if T_1 and T_3 are fixed temperatures, the intermediate temperature T_2 must be chosen as near to T_3 as practicable.

As an example, let

$$t_1 = 300° \text{ F.}; \quad t_2 = 100; \quad \text{and } t_3 = 60.$$

The heat rendered available by this process is

$$Q_1 \times \frac{560}{760} \times \frac{240}{40} = 4\tfrac{8}{19}\, Q_1$$

or more than four times the heat originally employed. In other words, one pound of steam at 300° F. would heat as much water to 100° F. by this process as four pounds would by mere conduction, provided the highest available temperature were 60° F.

During this process, the entropy has remained constant and,

consequently, the available energy unchanged. We are not, therefore, liable to imagine that this large amount of low temperature heat could be used to run a heat engine to give a better result than the simplest cycle, namely, from T_1 to T_3. In fact, if we use this heat in (6), to run a heat engine between T_2 and T_3, the heat equivalent of the work done is

$$Q_1 \frac{T_2}{T_1} \left(\frac{T_1 - T_3}{T_2 - T_3} \right) \frac{T_2 - T_3}{T_2} = \frac{Q_1}{T_1} (T_1 - T_3) \qquad (7)$$

or precisely the same as that of working the engine between T_1 and T_3.

But suppose the object of the combination is to lower the temperature of surrounding objects, say to T_4; in other words, to run a refrigerating machine in the most economical manner. Since for this purpose the complex cycle above described exists, it would seem possible to utilize the heat generated by the compressor or reverse engine to assist the direct heat—or steam engine.

The sum of the rejected heat of the heat engine; and that transferred by the reverse engine (which latter quantity includes the work which is re-converted into heat); is now

$$Q_1 \frac{T_2}{T_1} \left(\frac{T_1 - T_4}{T_2 - T_4} \right) \qquad (8)$$

which is less than in the previous case, since T_4 is less than T_3. It is, however, much greater than the simply rejected heat of the engine at T_2, and might justify the employment of an agent to run an engine between T_2 and T_3. Such an engine would develop work equal to

$$Q_1 \frac{T_2}{T_1} \left(\frac{T_1 - T_4}{T_2 - T_4} \right) \frac{T_2 - T_3}{T_2} = \frac{Q_1}{T_1} \frac{(T_1 - T_4)(T_2 - T_3)}{T_2 - T_4} \qquad (9)$$

which would be available for running the compressor in addition to the original work, $\frac{Q_1}{T_1}$ $(T_1 - T_2)$ of the steam engine.

As an illustrative example, let $t_1 = 300^\circ$; $t_2 = 100$; $t_3 = 60$; $t_4 = 0$; that is, the engine is run between t_1 and t_2, the refrigerating machine between t_2 and t_4, and the low temperature engine between t_2 and t_3. The work of the steam engine is

$$\frac{Q_1}{T_1} (T_1 - T_2) = \frac{200}{760} Q_1 = \tfrac{5}{19} Q_1$$

and that of the low temperature engine

$$\frac{Q_1}{T_1}\frac{(T_1 - T_4)(T_2 - T_3)}{T_2 - T_4} = \frac{300 \times 40}{760 \times 100} Q_1 = \tfrac{3}{19} Q_1.$$

Here the work available for running the refrigerating machine is increased sixty per cent. If the steam engine had been able to utilize the heat down to t_3, the work done would be

$$\frac{Q_1}{T_1}(T_1 - T_3) = \tfrac{6}{19} Q_1$$

the additional work due to the heat from the refrigerating machine giving an increase of fifty per cent. upon this. If this heat were really available, it might well be worth the expense of putting in a low temperature engine to utilize it. But this result could not be practically realized with advantage, for even if we admit that T_3, the refrigerator of the low temperature engine being unlimited, would remain constant, yet the economical working of the refrigeration machine requires that the temperature of its condenser, T_2, should be kept as low as possible; that is, as near to T_3 as practicable. Hence the factor $(T_2 - T_3)$ in (9) vanishes, and with it vanishes the possibility of employing the heat transferred by the refrigeration machine to assist it. We are confirmed in this conclusion if we observe the effect upon the efficiency of the refrigeration machine, which results from changing T_2 to T_3. The production is increased from $\frac{T_4}{T_2 - T_4} w$ to $\frac{T_4}{T_3 - T_4} w$, where w is the same amount of work employed in each case. In the example considered the production is increased in the ratio $\frac{T_2 - T_4}{T_3 - T_4} = \frac{100}{60} = 1.66$, or sixty-six per cent. While, therefore, it is possible to utilize the heat transferred to the condenser of the refrigerating machine, if the temperature is sensibly raised, to restore the loss caused by such rise of temperature, it is better to provide ample surface and active circulation to effect the transfer at the lowest possible temperature.

Although it is thus evident that this complex cycle cannot be made use of to increase the efficiency either of the steam (or other heat) engine or its reverse, the refrigeration machine, there yet remain two cases in which the indications of practical utility are sufficient to merit consideration.

(1.) Where the object in view is to obtain low temperature heat from a high temperature source.

(2.) Where the object is to extend the cycle of operation beyond the temperatures readily controlled by the ordinary form of heat engine.

It is obvious that the impossibility of practically realizing completely either portion of this complex cycle will prevent our obtaining results equal to those indicated. But it may be noticed that in the present case the losses arising from defects are not the same as in the case where the object sought is the conversion of heat into work. Thus, for example, the loss arising from the incompleteness of the cycle by reason of which we fail to convert the available heat energy into work, is not a total loss to us, but remains as heat, and so much of such available heat as is converted into work will effect, under favorable conditions, the transfer to the condenser of the reverse engine of a much greater amount than the converted heat, even though the reverse cycle be itself imperfect. This is evident from the fact that the heat so transferred is the sum of the heat equivalent of the work (which is reconverted into heat) and whatever refrigerating effect may be produced.

Hence, a refrigerating machine may be employed as a heating machine, and the simplest explanation of this fact is that it utilizes the available energy of high temperature heat (which is dissipated in the usual mode of heating) to effect the transfer of another quantity of heat from surrounding objects.

The obstacles to an increased range of temperature in the heat engine, and consequent increased efficiency are due almost entirely to mechanical difficulties. It is conceivable that a means of practically effecting the transfer of heat considered from a temperature beyond the control of the present form of heat engine, to one within its range may be found which will not involve the mechanical difficulties of the present heat engine. The effect of this would be to render the efficiency of an engine working between T_2 and T_3 equal to that working between T_1 and T_3, and the possibility of accomplishing this gives an interest to the second case.

As a matter of fact, we have an example of a transfer of heat approximately at least, in accordance with the cycle considered in the closed distillation process which practically combines an

engine and its reverse. In this apparatus the heat received by the condenser is the sum of that taken from the refrigerator and that part of the heat supplied by the still, which corresponds to the available energy of the steam engine, while that portion, also supplied by the still, which corresponds to the rejected heat of the engine, appears in the absorber. The moving parts in this mechanism are insignificant and, but slightly, if at all affected by the range of the cycle, being merely a pump to effect the transfer of the agents used from the absorber to the still. Moreover, since the losses arising from the difficulties of adapting the mechanism of the heat engine to the cycle of maximum efficiency, together with those arising from the dissipation of energy in running the same are absent we may expect a greater practical efficiency. A still greater efficiency may be looked for from the fact that the range of the cycle is not limited by the same conditions which are imposed by the ordinary form of heat engine. The only apparatus of this description with which we are practically acquainted is the ammonia distillation machine. It is possible that in very cold climates a combination of this with a single low temperature engine would be simpler than that of a high and low temperature engine, although as shown the theoretic efficiency of each combination would be the same. But for extending the cycle in the other direction where the option of employing two heat engines is less practicable, we are at present unacquainted with suitable agents.

Measure of Liquid Resistance by Alternative Currents.—Two methods have been employed for the exact measurement of the resistance of liquids; one, based upon the use of electrometers with an elimination of the influence of the polarization of the electrodes; the other, consists in weakening the polarization so that it may be disregarded while augmenting at the same time the useful surface of the electrodes, and having recourse to alternative currents of the shortest possible duration. This method has been often employed abroad, especially by F. Kohlrausch. Bouty and Foussereau have compared the results by the two methods, using a small Deprez motor with a velocity of 100 turns per second, directing the currents to a Wheatstone bridge, in which the galvanometer was replaced by an excellent Ader telephone. They find the precision of the measurements with electrometers much the most satisfactory. It seems, indeed, very difficult to apply with any success the method of alternative currents to liquors which are greatly diluted, or which present great resistance.—*L'Electricien, Aug. 15, 1885.*

A METHOD OF DESIGNING SCREW PROPELLERS.

By Christian Hoehle, Philadelphia, Pa.

In bringing my method of designing screw propellers before the engineering public, I do so with the conviction that the principles embodied in it are entirely novel and original, and that they will greatly aid in solving all questions relating to a subject on which so much has been said, written and experimented, and of which, according to all authorities, so little is yet known.

In the calculations necessary to determine the proper dimensions of a screw propeller for producing at a given velocity a thrust equal to the resistance of the vessel, a certain amount of slip is at present arbitrarily assumed. And it so happens that later on during the running of the vessel the actual slip very rarely, if ever, agrees with the assumed slip ; in fact, the difference between the two is generally very marked. Marine engineers have so far been unable to account for this perplexing difference for the simple reason, that they have not yet recognized on what properties of a screw propeller the slip depends. To point out these qualities and show how to obtain them is the main object of this article.

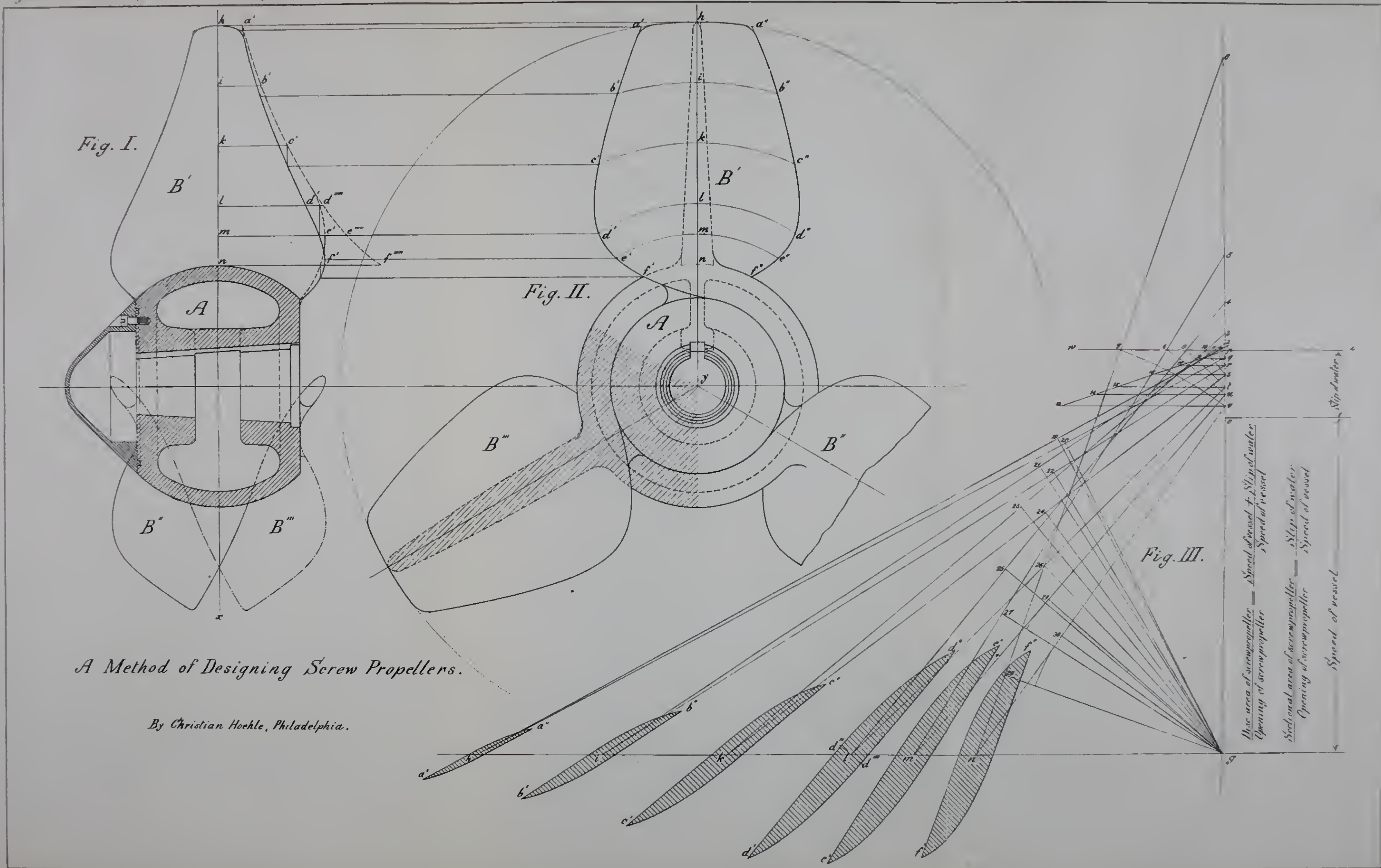
I believe everybody will agree with me when I assume that a good screw propeller, when driving a vessel, should affect only a column of water of a diameter equal to its own. For simplicity's sake, I will also assume that the vessel does not drag, so to speak, a body of water along with it and that therefore the velocity of the water approaching the screw is equal to that of the vessel. The difference of the disc area of the screw and its sectional area, as produced by a plane perpendicular to the axis at the centre of the hub, I call the opening of the screw. For a *properly* designed screw propeller, I now advance the proposition that *the velocity of the water passing through the opening of the screw is to the velocity of the vessel as the disc area of the screw is to the area of the opening.* And as the velocity of the water passing through the opening of the screw is equal to the velocity of the vessel plus the slip of the water, the above proposition may also be put into the following shape : *The slip of the water is to the velocity of the vessel as the sectional area of the screw is to the area of its opening.*

From these propositions it is at once apparent on what properties of a screw the slip depends.

I have said, however, that these propositions can be applied only to a *properly* designed screw, by which I mean one whose pitch increases from periphery to hub in a manner that with the aid of the accompanying drawing, I will now proceed to explain.

Fig. 1 represents a longitudinal section of a three-bladed screw propeller of my system; *Fig. 2* an end view of the same, showing also in dotted lines one-third of its sectional area as defined above and in blade B' its thickness at different radii. *Fig. 3* represents in a plane the cylindrical cross-sections of a blade at different radii, their respective pitch angles and the mode of determining them.

In *Fig. 3*, let $l\,g$ represent one-third of the circumference of a circle described with the radius $y\,l$ (*Fig. 2*) and let it also represent the circular velocity of the point l (*Fig. 2.*) On the same scale, let $g\,o$ represent the velocity of the vessel and $o\,p$ the slip of the water proportioned in accordance with the propositions presented above. Then I draw the two straight lines $l\,9\,4$ and $l\,t$ so that the line $l\,9$ is equal to the line $l\,t$, and so that the perpendicular $g\,25$ is equal to the perpendicular $g\,26$ plus the thickness $d'''\ d''''$ of the blade at the point l. Then $g\,t$ represents the velocity of the water on entering the screw. The resultant $l\,t$ of the two velocities $g\,l$ and $g\,t$ indicates the velocity of the water entering the screw obliquely, it remains constant while passing through the screw, but has its direction changed from $l\,t$ to $l\,9$. To recapitulate: the water approaches the screw with the velocity $g\,o$, enters it with $g\,t$ and passes through it with $g\,p$. The pitch angle of the cross-section in question is indicated by the angle $g\,l\,4$ and one-third of its pitch by $g\,4$. The perpendicular $g\,26$ represents the width of the *oblique* opening between two adjoining blades. By performing the above operation for the points h, i, k, l, m and n, I get their respective pitch angles $g\,h\,1$, $g\,i\,2$, $g\,k\,3$, $g\,l\,4$, $g\,m\,5$ and $g\,n\,6$; one-third of their respective pitches $g\,1$, $g\,2$, $g\,3$, $g\,4$, $g\,5$ and $g\,6$, and their respective widths of oblique opening $g\,20$, $g\,22$, $g\,24$, $g\,26$, $g\,28$ and $g\,30$. The velocity $g\,v$ with which the water enters the screw at the hub must never be less than the velocity $g\,o$ of the vessel. According to my method, therefore, *the pitch of a properly constructed screw propeller is smallest at the periphery and increases towards the hub, gradually at first and then more decidedly*



A Method of Designing Screw Propellers.

By Christian Hoehle, Philadelphia.

as the hub is approached. The slip of the water, as I have called it, is indicated by $o\ p$ and is the same at all points of the blade, while the slip of the screw as usually understood varies with the pitch, and for the points h, i, k, l, m and n is represented by $o\ 1$, $o\ 2$, $o\ 3$, $o\ 4$, $o\ 5$ and $o\ 6$. The two kinds of slip differ but very little at the periphery, and when speaking in a general way of the pitch and slip of my screw propeller, I mean those at the periphery.

If for a screw propeller, with a uniform pitch from tip to hub, the velocities with which the water enters the screw at the different points are ascertained according to my method, it is found that at the hub this velocity is considerably smaller than that of the vessel; in other words, it is reduced to allow the water to pass through the *contracted* oblique opening of such a screw. And this means that, with a uniform pitch, the parts of the blades nearest the hub not only do not produce any thrust, but actually create resistance. *A screw propeller with a uniform pitch is a bad one.*

The lines forming the cross-section, $d'\ d'''\ d''\ d''''$, consist of two straight lines, $d'\ d'''$ and $d''\ d''''$, parallel with the pitch line $l\ 4$, and the two curved lines, $d'\ d''''$ and $d''\ l'''$; the straight lines being tangent to the curved ones at the points d''' and d''''. According to the material of which the screw propeller is made, the curved lines are more or less flat and the edges d' and d'' more or less pointed. By forming the cross sections of the blades in this manner, the water is free to leave the screw in the same direction and with the same velocity that it entered, a point that I consider absolutely necessary for the efficient action of a propeller. It has been pointed out to me that this cross section of mine is the only weak point in my system, and that I cannot possibly produce any thrust with it, an objection which I meet with the fact that the very action I aim to produce in my screw propeller takes place in paddle wheels, both radial and feathering, and yet we all know that these contrivances answer their purpose admirably.

I now come to the question of blade-surface and its disposition. By again referring to *Fig. 3*, it is seen that the velocities of the water, while passing through the screw at the points h, i, k, l, m and n, increase by the amounts $q\ p$, $r\ p$, $s\ p$, $t\ p$, $u\ p$, and $v\ p$. Now the time necessary to produce these increases in the velocities is, according to the laws of uniformly accelerated motion, directly

proportional to them, and therefore determines the relative lengths (parallel with the axis) of the blade at the different points. These half lengths are represented by *v 13*, *u 14*, *t 15*, *s 16*, *r 17* and *q 18*, and, on being transferred to *Fig. 1*, produce the curved line a' b' c' d''''' e''''' f''''', which, in order to meet the hub, I change to a' b' c' d' e' f'. I am not a mathematician, but I am perfectly aware that this last demonstration of mine is not mathematically correct, but I believe it to be sufficiently so for all practical purposes.

In conclusion, I frankly acknowledge that I have neglected to take into consideration several very important matters, namely, the shape of the vessel, the thickness of the stern and rudder-posts, and the diameter of the hub of the sternpost. At present I am unable to say in what way and to what extent they would tend to modify my system of constructing screw propellers. Neither did I take any notice of the friction caused by a screw in passing through the water, as I believe that by designing a screw propeller otherwise rationally, more will be gained than can possibly be lost by friction.

Rope Railway at Genoa.—A rope railway is to be built at Genoa, from Balzaneto to the sanctuary of the Madonna de la Garde. Instead of a stationary engine which acts directly upon the endless cable, the locomotive which conducts the train from Balzaneto to the foot of the hill will be detached, and its wheels will serve as pulleys for the cable. It is thought that this arrangement will be much more economical than that of a stationary engine, which would necessarily have a horse-power greater than would often be needed.—*Cosmos, Sept. 28, 1885.*

Spectral Analysis of Atmospheric Elements.—The study of the spectra of the atmospheric gases and vapors is of especial importance in astronomical physics in as much as it furnishes one of the principal bases for inferences as to the composition of planetary and stellar atmospheres. The Meudon observatory has great facilities for the employment of solar, electric and other lights, and for arranging in a single hall a series of experiments 120 metres long. Janssen is experimenting upon hydrogen, oxygen and atmospheric air in four tubes, all of which are strong enough to support pressures of nearly thirty atmospheres, and one of which is sixty metres long. In addition to the lines and bands which were first pointed out by Egoroff, he has already found absorption phenomena beyond A., and three obscure bands, one in the red, one in the yellowish-green and one in the blue, which can hardly be attributed to the oxygen in the condition in which it exists in the terrestrial atmosphere.—*Comptes Rendus, Oct. 5, 1885.*

CORRECT COLOR-TONE PHOTOGRAPHY WITH ORDINARY GELATINE BROMIDE PLATES.

By Fred. E. Ives.

[*Paper read at meeting of* Franklin Institute, *June 16th. Revised and presented for publication June 18th.*]

Chlorophyl-stained collodion bromide emulsion plates have been made four or five times more sensitive to spectrum red than to blue. It has been estimated that ordinary gelatine bromide plates are 100 times more sensitive to blue than to red. The *relative* red sensitiveness of the chlorophyl-stained collodion plates is, therefore, probably 400 or 500 times greater than that of ordinary gelatine bromide plates. But the most rapid ordinary gelatine bromide plates are 100 times more sensitive to ordinary diffused daylight than the collodion emulsion plates, and it would, therefore, appear that the absolute red sensitiveness of the very rapid gelatine plate should be one-fifth as great as that of the very slow chlorophyl plate. By recent experiment in photographing the lime-light spectrum, I have found this estimate to be very nearly correct for some makes of extra rapid gelatine bromide plates.

What, then, is to prevent us from making correct color-tone photographs with very rapid ordinary gelatine dry plates? The difficulties, although apparently great, are not insurmountable, as I shall show; but the exposures are necessarily so long that the method is not available in many cases where the regular isochromatic processes can be successfully employed. I have calculated that, in order to secure correct color-tone without a color-screen, it would be necessary to have plates about ten times as sensitive to spectrum red as to blue; if this estimate is correct, the ordinary rapid gelatine dry plate is relatively 1,000 times too sensitive to blue, and in order to secure correct color-tone with such a plate it would be necessary to cut off $\frac{999}{1000}$ of the blue light, and green and yellow in due proportion. It is very easy to cut off a large portion, or all, of the blue light, but it required a great deal of patient experiment to produce a color-screen that cut off just enough of the blue, and also of the green and yellow. I accom-

plished this by a mixture of aniline color solutions in the plate-glass tank which I recommended for color-screen purposes, in 1879. My first trial exposures were made on the lime-light spectrum. I commenced by adding aniline yellow to water in the tank, a little at a time, until so little blue light was transmitted that it produced very much less action than the red; I then added aniline red until the green acted but little more than the blue, and aniline violet to slightly reduce the action of the yellow. An exposure made in the camera, using this color-screen and a M. A. Seed plate, proved that my calculations were very nearly correct. I was only obliged to add a little more yellow and red to the color solution to secure correct color-tone in all the colors of a bright chromo, which I use as a test object. *With exposures five times longer*, I have secured results apparently equal to those obtained with my chlorophyl-eosine plates and yellow screen.

The result which I obtained cannot be even approximated by means of a screen of any single-color solution that has been tried, and I believe this to be the first specification of the production of a color-screen actually capable of securing correct color-tone with ordinary plates.

RELATION OF VAPOR TENSION TO INTERNAL FRICTION.—The phenomenon of diffusion and the displacements of minute particles which are introduced into liquids show that liquids are formed of molecules, which are endowed with a perceptible movement of translation. Vaporization is, therefore, easily explained by attributing to some of the molecules a *vis viva* sufficient to project them beyond the sphere of activity of the superficial molecules. If we adopt this explanation, the vapor tension must be intimately connected with the molecular velocities, which are themselves a function of the coefficient of internal friction. P. De Heen has found an empirical formula, which represents very closely this theoretical ratio in all the bodies upon which he has experimented. Designating by p the vapor tension taken at the absolute temperature T, and by f the coefficient of friction at the same temperature, we have $T f \log. p =$ const.—*Bul. de l'Acad. de Belg., No. 8, 1885.*

GEOLOGICAL THERMO-CHEMISTRY.—In order to determine the influence of thermo-chemistry in the production of metallic ores, Dieulafait assumes that if we study each metal and find which of its natural combinations develops the greatest heat, that combination will be found to represent the principal ore of the metal under consideration. He has tested his theory by the four most frequent ores of manganese, and finds it to be satisfactorily confirmed. —*Comptes Rendus, Oct. 5, 1882.*

SUGGESTIONS TOWARDS A SIMPLIFIED SYSTEM OF WEATHER SIGNALS, TERMED THE INDEX WEATHER SIGNAL SYSTEM.

BY JOSHUA PUSEY.

[*Presented at the Stated Meeting of the* FRANKLIN INSTITUTE, *held June 16, 1886.*]

In the effort to learn and to recollect the well-known weather signals now in use, consisting of the red and blue suns, stars and crescents, I was struck, as others have doubtless been, with the difficulty of fixing and retaining the same in memory because of the confusion of arbitrary colors and forms. It occurred to me that a system might be devised which would possess the salient advantages of being simpler, independent of essential color and form, readily learned and recollected, and more economical than the system now in vogue.

My reflections upon this subject led me to devise the system which I shall now proceed to describe, premising, however, that, although it is not claimed to be perfect, it is thought to be better than that in use.

In this system, movable signal bands are used in connection with a flag, or rotatable pointers pivoted on a common centre, as hereinafter described.

Referring to the drawings, *Fig. 1* represents a flag, *A*, preferably white, having a vertical black stripe or bar *b* (termed the general rain or snow bar) at one side of the centre. The flag is always hung with this stripe in vertical position. The flag is divided into six (imaginary) fields, three of which are horizontal *temperature* fields and three vertical *weather* fields.

The top or higher part is the *higher* temperature field; the bottom the *lower* temperature field, and between the two the *stationary* temperature field. These fields are suggested by the relative position of the mercury in the thermometer, which is higher with higher temperature, etc.

One side or edge of the flag is the *local* rain or snow field; the other (indicated by the black stripe *b*) is the *general* rain or snow field, and between the two the *fair* or *clear* weather field.

Fig. 1.

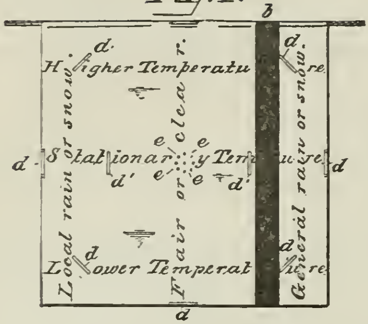


Fig. 2.

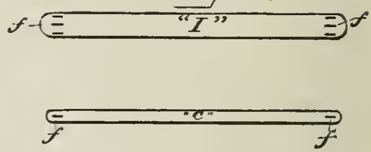


Fig. 3.

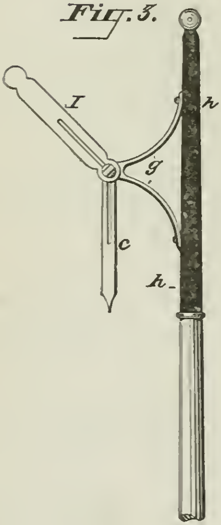


Fig. 4.

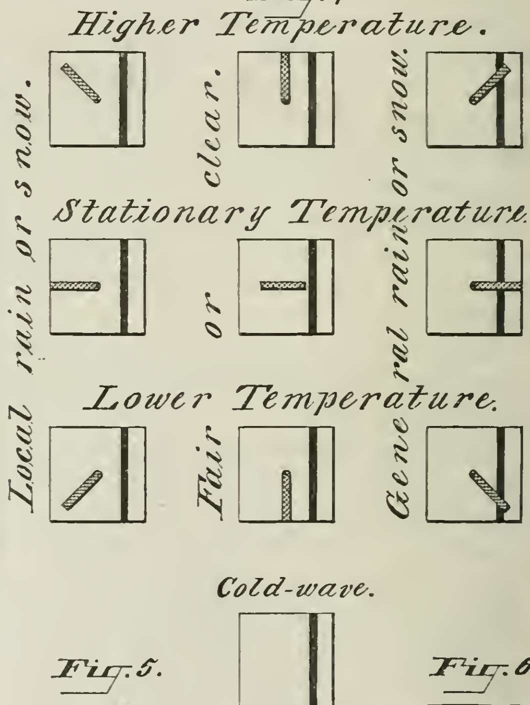


Fig. 5.

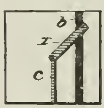
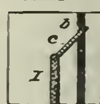


Fig. 6.



Proposed System of Weather Signals. (Pusey.)

All that is essential to be learned is the locations of these three temperature and three weather fields, which may be quickly and permanently done.

To indicate the particular signals required—both temperature and weather being indicated at the same time—I employ two bands, *Fig. 2*, of silk or bunting, one of which, *I*, is broad and is termed the "index," and whose function is to indicate the immediate probabilities; and the other, *c*, relatively narrow and termed the "change" or follower band, whose function is to indicate the weather probabilities following those indicated by the index band. The obvious object of this marked difference in the widths of these bands is to enable the one to be readily distinguished from the other. Their particular color or colors is unimportant, so that they be in strong contrast to that of the flag. Red for the index and blue for the change are preferred.

The flag is provided with button-hole slits *d*, equidistant from the centre, with the single exception of two slits (marked *d'*), a line connecting which slits traverses the stationary temperature and fair or clear weather fields.

At the centre of the flag, on both sides, are buttons *e*, for attaching the ends of the two bands, *I* and *c*, which are provided with button-holes *f*, at each end.

The bands are passed through one of slits *d*, according to the signal to be displayed, and the ends respectively are buttoned on both sides of the flag.

For the stationary temperature, clear or fair weather signal, the band or bands pass through the slits *d'*, so that the band will be in the two fields at the same time.

When a large flag is used, the bands may be further kept in place by means of light transverse straps at suitable intervals apart, the bands being passed under said straps.

When it is not desirable to use a flag, a device similar to that shown in *Fig. 3* may be employed. This consists of a kind of "semaphore," composed of bands or pointers, *I* and *c*, corresponding to the index and change bands for the flag.

The pointers swing from a pivot *x* at the junction of the ends of a bracket *g* that is fixed to and some distance below the top of a pole *h*. The former may be brought to any required position and there held by means of a thumb screw or other device. The

upper portion of the pole takes the place of the general rain or snow bar *b* of the flag.

The pointers are provided with longitudinal slots *s*, so as to allow them to be shifted towards the pivot, in order to make the stationary temperature clear or fair weather signal.

In order that the signals may be seen from any direction, there may be two sets of pointers connected with the pole in planes at right angles to each other.

Frequently, and in fact generally, the change signals are not used, in which case the narrow or change pointer may be turned back of the broad one and thereby be concealed from view. The pointers are removed for the cold-wave signal, and the flag is left bare for the same signal.

The diagrams, *Fig. 4*, show all the various signals. These correspond with those with which the general public is familiar. Cautionary or other signals may be made, if desired, by adopting arbitrary or, perhaps, suggestive shapes or colors for the pointers or bands.

To illustrate the difference between this system and the one now in use, the signal "higher temperature, local rain or snow," at the top of *Fig. 4*, on the left side, is made in the latter system by means of a flag with a red sun and one with a blue star.

The signal, *Fig. 5*, "higher temperature, general rain or snow, followed by lower temperature, fair or clear weather," is indicated in the present system by four flags in succession, to wit, a red ball, a blue ball, a red crescent and a blue crescent.

The signal, *Fig. 6*, "lower temperature, fair or clear weather, followed by higher temperature, general rain or snow," is indicated in the latter system by a red crescent, a blue crescent, a red ball and a blue ball.

It will be observed that the broad, or "index," band or pointer is always read first.

It may also be remarked that the signals in the proposed system form a straight line diagram; that is to say, the pointers or bands with the black stripe, or general rain bar. Thus a person glancing at the flag, or semaphore, will have the particular signal diagram impressed upon his mind, and will be able to carry it in memory for the day; whilst it is extremely difficult

to recollect the suns, stars and crescents, and their colors and order of succession, when several signals are displayed.

The salient advantages of the proposed system may be summed up as follows:

(1.) It is simple and suggestive, and readily learned and fixed in the mind, because of a certain easy association of ideas.

(2.) There is no confusion of colors and forms.

(3.) The signals being indicated by *direction*, they may be distinguished at long distances, far beyond those at which the *colors* of the suns, stars, etc., of the present system and their *forms* can be made out, unless of comparatively large dimensions.

This is especially the case with the semaphore construction, as the direction of the bands, or pointers, can be seen with the naked eye a distance of several miles.

(4.) It is much more economical, the cost of the one flag with bands, or the semaphore, being but a fraction of that of the flags required in the system now used.

HERSCHEL vs. JEVONS ET AL.

By Pliny Earle Chase, LL. D.

In the Journal of the Franklin Institute, for January, 1885, (p. 39), I pointed out "An Error by Maxwell," arising from a simple transposition of figures, a mistake with which all book-keepers are familiar. The error has led many recent writers, in popular text books and scientific journals, to assign to the luminiferous æther a density seventy-five per cent. greater than is justified by Maxwell's hypothesis.

An error of much greater importance has arisen from a misinterpretation of some passages in Herschel's "Lectures on Light." Jevons says (*Principles of Science*, ii, 145), "Sir John Herschel has calculated the amount of force which may be supposed, according to the undulatory theory of light, to be exerted at each point of space, and finds it to be 1,148,000,000,000 times the elastic force of ordinary air at the earth's surface, so that the pressure of the æther upon a square inch of surface must be about 17,000,000,000,000, or seventeen billions of pounds; yet we live and move, without appreciable resistance, through this medium

indefinitely harder and more elastic than adamant. All our ordinary notions must be laid aside in contemplating such an hypothesis; yet they are no more than the observed phenomena of light and heat force us to accept."

Fiske (*The Unseen World*, p. 20,) and Prof. De Volson Wood (*P. Mag.* [5] 20, p. 390,) write under the same misapprehension, overlooking the precaution which Herschel had taken to define his hypothesis, "that an amount of our ethereal medium equal *in quantity of matter* to that which is contained in a cubic inch of air [which *weighs* about one-third of a grain], were enclosed in a cube of an inch in the side," by italicizing the words which show that he was considering the *ratio* of elasticity to density, and not the simple elasticity.

Maxwell (*Enc. Britan.*, 9th Eng. edition, Art. "Ether") gives for the density of air at an infinite distance from the earth, 3×10^{327} less than his estimated density of æther. Applying the corrections which are required by his transposition, and interpreting his meaning as Jevons and many others have interpreted Herschel's, we should infer an æthereal pressure of more than 10^{324} tons per square inch, instead of $\frac{1}{6,820}$ of an ounce, which is the value legitimately deducible from Herschel's hypothesis. The weight of the cubic inch of æther would be only $\frac{1}{2,467,500,000,000,000,000,000}$ of an ounce, according to the same hypothesis.

Prof. Wood's mistake is the more remarkable from the fact that he proceeds precisely according to Herschel's methods, and obtains results which are substantially the same as Herschel's, although he supposes them to be new.

Insect Vision.—F. Plateau has published a preliminary notice of some investigations in regard to insect vision. He refers to various hypotheses of Müller, Exner, Nuel and Carrière, and after recounting his own experiments he deduces the following provisional conclusions: (1.) Diurnal insects need a strong light, and are unable to direct their flight in a semi-obscurity. (2.) The simple eyes of diurnal insects, which are provided with compound eyes, are of so little use that they may be rightly regarded as rudimentary organs. (3.) Insects with compound eyes take no account of the differences of form between two illuminated openings, and are easily deceived, either by excess of luminous intensity or by apparent excess of surface. In other words, they either do not distinguish the form of objects at all, or they distinguish it very imperfectly. In these experiments, the insects were placed in such conditions that they could be guided neither by color nor by smell, but were obliged to depend upon sight.—*Bul. de l'Acad. de Belg., No. 8, 1885.*

BAIRD'S ANNUNCIATOR.

FRANKLIN INSTITUTE, PHILADELPHIA, Pa.

THE COMMITTEE ON PUBLICATIONS:

Gentlemen:—In the JOURNAL for January, of this year, I find an interesting description of a "Steam Vessel Indicator," page 82. The inclosed report, I think, would supplement that item. The report in question was prepared for the use of the engineers using the machines.

The objects of the "Steam Vessel Indicator" and my Annunciator are not identical, in that the former indicates the position of the reversing gear and the throttle, while the latter indicates whether the engine is revolving, and in which direction, and also its approximate velocity.

The "Steam Vessel Indicator" might indicate the link in ahead motion and throttle wide open, but if the engineer has his cut-off far on, or his valves lapped, the engine will not move, though the indicator may lead pilot to believe it is going. As the annunciator is already adopted by the Navy, its publication in the JOURNAL would not be out of place, considering the number of Navy engineers who read the JOURNAL.

With great respect,

Your servant,

G. W. BAIRD,

Nassau, N. P., February, 1886. *P. A. Engineer, U. S. N.*

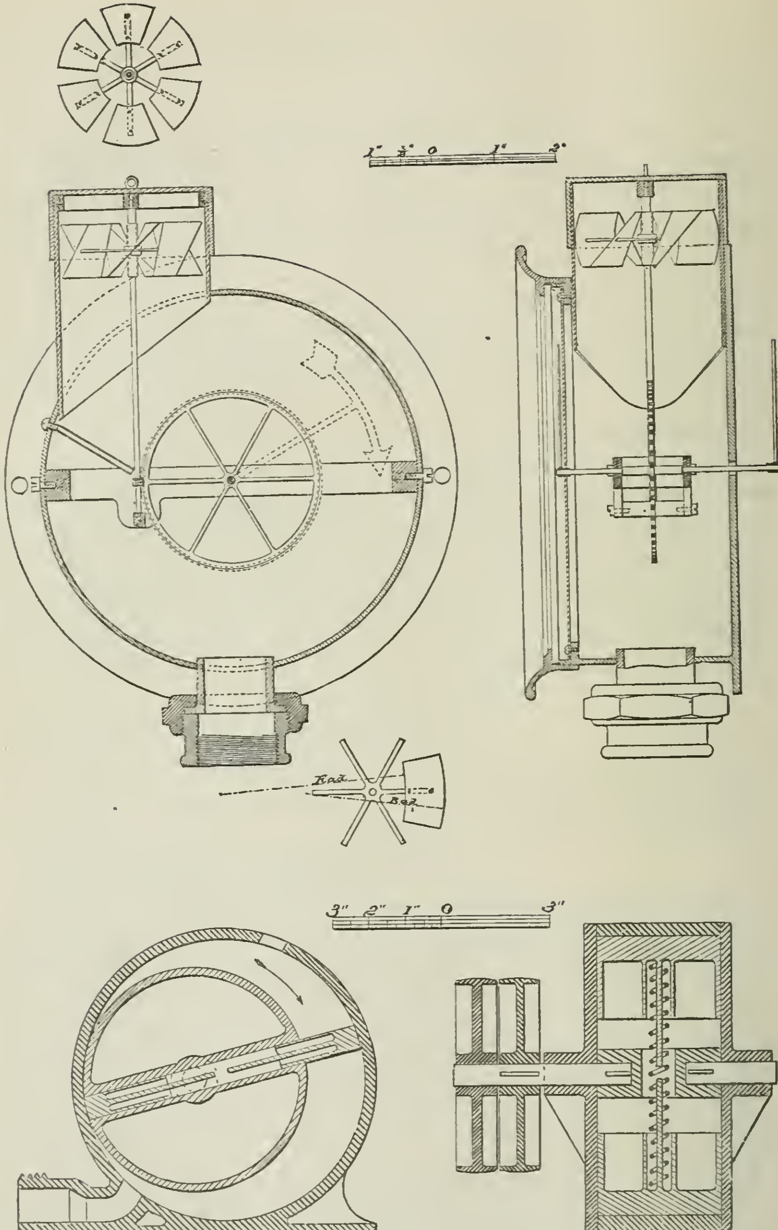
CHIEF ENGINEER'S OFFICE, U. S. NAVY YARD,
WASHINGTON, December 19, 1885.

Sir:—In compliance with instructions of the Bureau of Steam Engineering, dated the 15th, and your order dated the 16th instant, the Board appointed to examine the device described as "Baird's Annunciator," have examined the apparatus, observed its operation, and beg leave to report as follows:

The object of the device is to indicate upon deck, to the easy inspection of the officer in charge of the deck or his assistants, the direction of the movement of the engines, whether ahead or aback.

While the engines are working ahead an index revolves in the direction in which an arrow, on its free extremity, points; upon reversing the engines the motion of the index is reversed.

The mechanism immediately employed in producing these movements is enclosed in a case, of which the dial over which the index revolves is the face. The index is mounted upon a shaft or spindle, which carries a toothed wheel.



Baird's Annunciator.

The wheel and spindle are turned by the revolutions of a second spindle placed at right angles with the first, carrying a worm or endless screw, the threads of which mesh with the teeth of the wheel. The second spindle carries also a series of fans, arranged like the blades of a screw propeller, or like the vanes of the common anemometer.

By means of an air current, which flows in one direction when the ship's engines are going ahead, and in the opposite direction when they are backing, the fans and their spindle are rapidly revolved, and the proper motion transmitted through the spiral gearing to the index. The movement of the index is moderate in speed, but the speed is variable with the speed of the engine, and incidentally affords a means of estimating, by the eye, the speed as well as the direction of the movement of the engines and the ship.

The air current is derived from a small rotary blower, placed near the engine shaft, and turned by it through the operation of belts. When turned in one direction, the blower draws the air from the vanes of the annunciator through a pipe, in one enlarged extremity of which, forming a mouth, the vanes revolve. When turned in the opposite direction, the air is driven through the connecting pipe to the vanes, and the direction of the movement of the latter, upon the instant, reversed.

It is a very great advantage to the person manœuvering the ship, to know, without the delay attending inquiry, or observation of the movement of the ship herself, exactly what the latter is to be. Should mistake be made, it will be apparent before it is too late to correct it.

The apparatus is simple and elegant, the power consumed by it is inconsiderable, and it is not at all likely to get out of order.

Its first cost needs never to be great, and the cost of maintenance trifling. Drawings of it are hereto appended.

The Board recommends it for purchase and use for purposes under cognizance of the Bureau of Steam Engineering.

We are, Sir, very respectfully,

Your obd't serv'ts,

Charles H. Baker,
Chief Engineer, U. S. N.

R. D. Taylor,
P. Asst. Engineer, U. S. N.

R. R. Leitch,
P. Asst. Engineer, U. S. N.

Commodore W. W. Queen, U. S. N.,
Commandant.

RAPID TRANSIT AND ELEVATED RAILWAYS.

Committee on Publications:

Gentlemen:—I send the following, to print as a note in the Journal, if you see fit.

Note.—The engine for the new Meigs elevated railway system

was steamed up and run for the first time January 3, 1886, the driving wheels being prevented from touching the track. The following day, the locomotive was run upon the track.

On Friday, April 16, 1886, the first train, consisting of engine, tender and passenger car, the latter over fifty feet in length,* was made up and started at 3.15 P. M., going around a semi-circular curve of 50 feet radius, built upon an ascending grade of 120 feet to the mile. On Monday, April 19th, the Legislative Joint Committee (Mass.) on Street Railways, visited the works, and the engine mounted the 345 feet grade without the slightest difficulty.

A loosely-fastened rail was ripped off without any effect to the train. The experiment was perfectly successful, and all present were much pleased with the exhibition and listened with the closest attention to Capt. Meigs' explanations.

It need hardly be said that these are facts never before accomplished in railroading, and the new region of possibilities thus opened must produce results of a practical value beyond what can be, at this time, foreseen. In a few days the rolling stock will become sufficiently "limbered up" to make the trips around Capt. Meigs's difficult piece of track with ease, the entire safety from derailment having been already fully demonstrated.

F. E. GALLOUPE.

Boston, April 24, 1886.

ELECTRIC LIGHT FOR LABORATORY INVESTIGATION.—M. de Lacaze-Duthiers uses, in his Sorbonne laboratory and in his zoölogical stations at Roscoff and Banyuls, an electric lamp constructed by Trouvé, which would also be useful in much chemical, botanical and mineralogical work. It is composed of a cylindrical glass vessel, beneath which is a mirror of silvered glass. There is a silvered parabolic covering, in the centre of which is suspended an incandescent lamp. The vessel is filled with sea-water containing corals, polyps, sea worms and other objects which can be examined by the aid of magnifying glasses, the whole mass being thoroughly illuminated, as in the brilliant experiment of the illuminated fountain. The apparatus can be readily modified for the study of fermentation, and for dissecting, with great ease, nervous filaments of the greatest delicacy, which are hardly visible in the broad light of day. The generator of electricity is Jamin's universal automatic battery, weighing less than three kilogrammes.—*Comptes Rendus, Aug. 3, 1885.*

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* The full description was published in the JOURNAL, January–April, 1886.

REPORT OF THE COMMITTEE ON SCIENCE AND THE ARTS ON THE BILGRAM BEVEL GEAR CUTTER.

HALL OF THE FRANKLIN INSTITUTE,
Philadelphia, April 29, 1886.

The Sub-Committee of the Committee on Science and the Arts, constituted by the FRANKLIN INSTITUTE of the State of Pennsylvania, to which was referred for examination

HUGO BILGRAM'S BEVEL GEAR CUTTER,

Report: That the description and the copy of Patent No. 294,844, appended to these papers, contain a full and clear explanation of the construction and operation of the Bevel Gear Cutter; and that the extract from the JOURNAL OF THE FRANKLIN INSTITUTE of January, 1882, also appended, explains the theory upon which the machine is based.

After a critical examination of the machine and its product, and a careful study of the theoretical demonstration, we consider this a remarkable example of original invention. It is original in introducing the "path of contact," instead of the rolling curves, as a base for the theory of gear wheels; in introducing a new odontograph, in which a portion of a rack is used to delineate or envelop on a wheel a tooth form, which will properly gear with this rack or with any other wheel whose teeth have been delineated by the same rack; and in designing and constructing a machine for cutting theoretically perfect teeth in bevel gears, the adjustment, manipulation and operation of the machine being all that could be desired and the gears cut by it being superior to anything of their kind, known to your Sub-Committee.

We therefore recommend the award of the ELLIOT CRESSON GOLD MEDAL to HUGO BILGRAM for his Bevel Gear Cutter.

WM. H. THORNE, *Chairman.*
WILFRED LEWIS,
CARL BARTH,
LUTHER L. CHENEY,
OTTO C. WOLF,
C. CHABOT,
THOS. SHAW, M. E.

Adopted June 8, 1886.

H. R. HEYL, *Chairman.*

APPENDIX.

(*Accompanying Committee's Report.*)

In a paper read before the FRANKLIN INSTITUTE, November 16, 1881, entitled "A New Odontograph" (FRANKL. INST. JOURN., Jan., 1882), the author* remarks that "the principle of this odontograph may even be used in the construction of a gear-cutting machine, to give theoretically correct shapes. Suppose a shaping machine, provided with a tool of the shape of a rack tooth, would, by the cross-feed, produce a simultaneous rotation of the wheel to be cut, or rather corrected, say by means of a thin steel band running over a cylinder of the diameter of the pitch-circle of the wheel. This operation is identical with the above-described application of the odontograph. The same tool will give the proper form to all wheels, large or small, of the same set. This plan would even be applicable to the cutting of theoretically correct bevel wheels, by cutting only one side of a tooth at one time, especially if the involute form of teeth is adopted. For practical reasons, however, it is doubtful whether such machines would be commercially successful."

This suggestion has since been carried out by the construction of machines for cutting bevel gears, and the excellence of the work produced confirms the correctness of the theory stated, at the same time dispelling the doubts of commercial success.

The machine, as represented in the accompanying cut, consists of a mechanism for imparting to the blank to be cut, the necessary rolling motion, and of a shaper-like tool-moving device.

The compound movement of a cone, rolling on a plane surface, can be resolved into two simple movements. The first is an imitation by the axis, of the movement of a conical pendulum, and the second is a rotation of the cone on its axis. These movements are accomplished as follows: The arbor, carrying the blank to be cut, is secured in an inclined position to a semi-circular horizontal plate, which can be oscillated on a vertical axis passing through the apex of the blank. To complete the rolling action, a portion of a cone—coinciding with the pitch cone of the blank—is attached to the arbor and held by two flexible steel bands, stretched in opposite directions, which confine the cone to a purely rolling motion as the semi-circular plate is moved, for the purpose of imparting to the arbor the necessary swinging motion. The rolling cone, which is

* By Hugo Bilgram, M. E.

held by the flexible bands, is placed on the side of the apex opposite that to which the blank is secured, to avoid interference with the tool.

The feed mechanism imparts a slow intermittent movement to

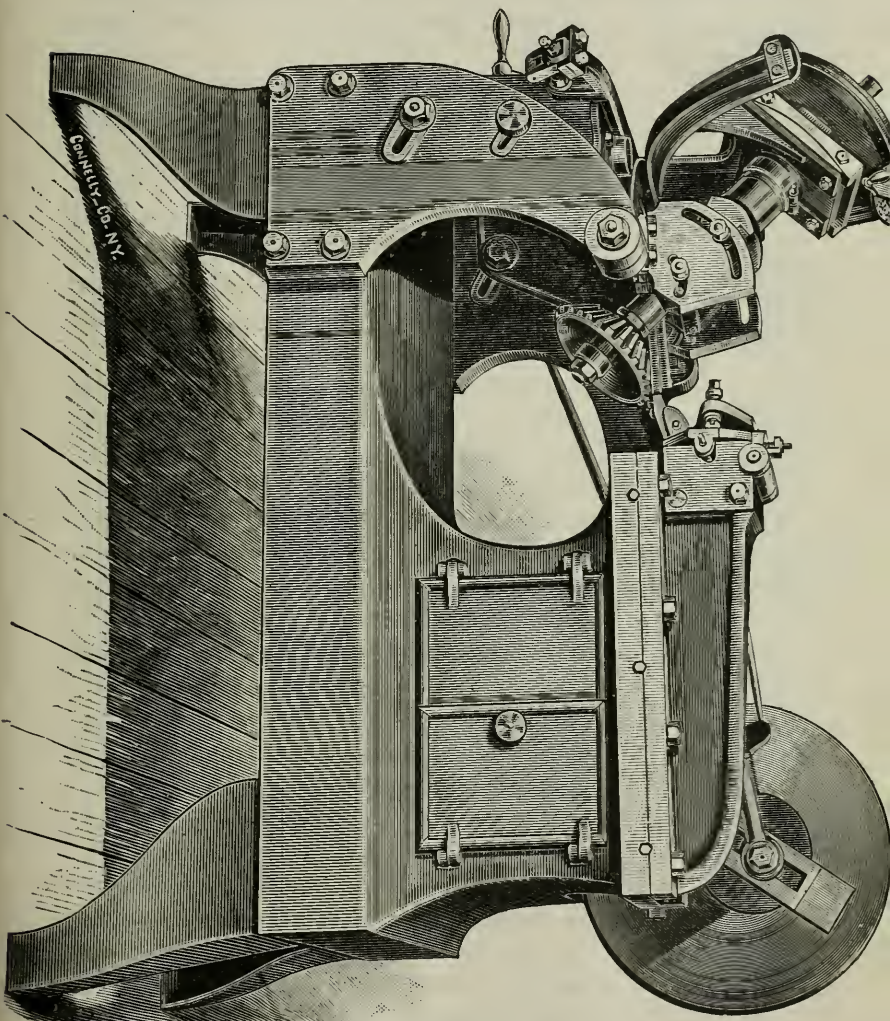

FIG. 1.

the semi-circular plate supporting the inclined arbor. A slowly progressing rolling of the blank ensues while the reciprocating tool cuts its way through the metal. The reversal or disengagement of the feed is in the power of the operator.

The arbor carrying the blank can be rotated independent of the

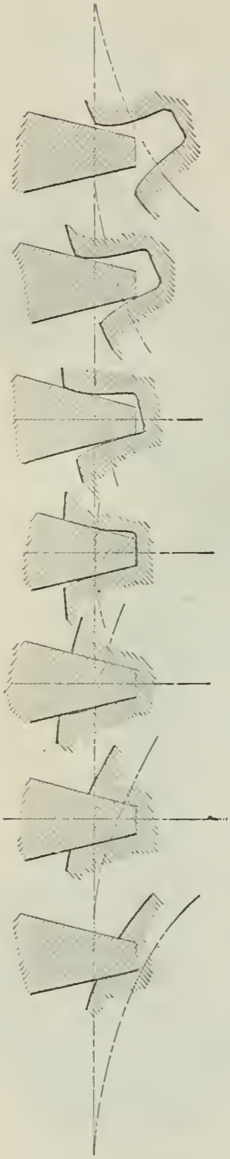

FIG. 2.

rolling cone by means of a worm wheel, worm and index plate, which enables the blank to be presented to the cutting device at properly spaced divisions corresponding with the number of teeth of the desired wheel.

The accuracy of the product of the machine depends largely on the proper adjustment of the cutting tool, to effect which a gauge is provided. A distance block is used between this gauge and the tool; this mode admits of a high degree of accuracy, since variations of distances can readily be detected by the touch when the eye ceases to discern.

When a wheel is to be cut out of the solid, the tool is at first adjusted at a slight distance from its correct position, and after each cut the feed motion of the evolver causes the blank to slowly roll, and allows the tool to cut out the stock in the manner shown in the diagram. All spaces are now treated in the same manner by using the index device, whereupon the tool is properly adjusted for one and then for the other side, each adjustment being followed by a repetition of the process in order to finish both sides of the teeth.

A special device enables the operator to gauge the distance of the ends of the teeth from the centre of the revolving mechanism, at which the apex of the blank must be placed. When this measurement coincides with the previously computed distance, the blank is properly located.

The inclination of the arbor, which holds the blank, is made adjustable, so as to adapt it to the angle of the desired gear. This adjustment must be exactly concentric with the apex of the blank. The rolling cone is made detachable, in order that it may be

replaced by such cones as correspond with the angle of the blank to be cut.

The tool consists of a triangular bar of hardened steel, forming at the point an angle of 30°, 15° on each side, and held by a special holder. By grinding, it can be more or less truncated to suit the pitch of the gear to be cut. By this form of tool a much higher degree of accuracy is attainable than with tools having curved faces made to a templet. The proper up and down and sideway adjustment is effected by two slides working at right angles, and operated by screws. The clamp, which fastens the tool-holder, is so constructed that it also clamps these said slides to the apron, securing the necessary stability. The apron is fitted with great care; the box in which the apron works is made in parts, and the faces are turned true with the pin-holes, in order to get these faces exactly at right angles with the pin. The latter is fast in the apron, and revolves in the two sides, in which it has taper fits that the wear may be taken up. A device for lifting the apron during the return stroke prevents the dragging of the tool. The oscillating movement of the connecting-rod is employed for this purpose, by having a bar hinged at one end to a clamp, which can be shifted on the connecting-rod while the other end impinges on the apron. By a lifting of the crank end of the connecting-rod, the loose end of this bar is pushed forward and the apron is lifted. It is easy to so adjust the clamp that this lifting action will occupy the time of the return stroke.

The tool-bar is moved by a Whitworth quick-return motion, which is attached directly to the belt pulley. A double countershaft, connected by cone pulleys, is employed to change the speed if a shorter or longer stroke is desired.

Gears cut on this machine are practically as nearly perfect as it is possible to produce plane surfaces on a planer. For this reason a careful preparation of the blanks is essential.

REPORT OF THE COMMITTEE ON SCIENCE AND THE ARTS ON THE PRATT & WHITNEY SYSTEM OF INTERCHANGEABLE CUT GEARS.

HALL OF THE FRANKLIN INSTITUTE,
Philadelphia, May 5, 1886.

The Sub-Committee of the Committee on Science and the Arts,

constituted by the FRANKLIN INSTITUTE, of the State of Pennsylvania, to which was referred for examination

THE PRATT & WHITNEY SYSTEM OF INTERCHANGEABLE CUT GEARS

Report: That they have carefully examined the matter submitted to them.

The application relates to a system for producing epicycloidal spur gears of a very high degree of perfection.

The first process in the system consists in procuring accurate templets for making the cutters. These templets are produced on a machine in which a rotary cutter is guided in epicycloidal and hypocycloidal paths by the actual rolling of describing circles on a circle representing the pitch line of the wheel. The difficulty of passing the cutter from the epicycloidal path of the face of the tooth-templet to the hypocycloidal path of the flank is met by a most ingenious device deserving the highest commendation. The machine is minutely described in the pamphlet accompanying this report. On this machine a complete set of templets of only one pitch can be produced.

The second machine is designed to make the properly formed rotary cutters. The templets are used to guide the tool, and in this manner the formed cutters obtain the exact shape by positive machine movements without the aid of skilled labor or hand-work. By the application of the pantographic principle, cutters of any pitch can be made from the one set of templets prepared on the first machine. For a detailed description of this machine, we again refer to the pamphlet accompanying this report.

The specimen gear wheels and rack which have been furnished, exhibiting the work performed by such cutters, confirm the conclusion that a high degree of accuracy can be attained by this process.

Your Sub-Committee have concluded to recommend the award of the ELLIOT CRESSON GOLD MEDAL, for the conception and putting into practice the system of producing cutters, and the SCOTT LEGACY, MEDAL and PREMIUM, for the ingenuity displayed in the detailed construction of the machine.

Respectfully submitted,

HUGO BILGRAM, *Chairman.*
C. CHABOT,
LUTHER L. CHENEY.

Adopted June 8, 1886. H. R. HEYL, *Chairman.*

THE "NOVELTIES" EXHIBITION OF THE FRANKLIN INSTITUTE, 1886.

ABSTRACTS OF REPORTS OF THE JUDGES.

(*Continued from page 80.*)

GROUP 5*a* 5*b*.—COAL, MINERALS AND METALLURGY, METALLURGICAL PROCESSES AND PRODUCTS.

Judges:—Samuel R. Marshall, *Chm.*; W. H. Blake, M. D., D. E. Rice, M. D.

C. H. DELAMATER, NEW YORK.

The Waring Centrifugal Pulverator.—For the pulverizing of ores, phosphates, rock, cement, etc. The judges consider it well calculated to sustain the maker's claims and think it the best and most desirable machine now in use in respect to efficiency, economy of labor and power with the minimum of wear. (*A Silver Medal.*)

GROUP 6.—DISTILLATION, BREWING, REFRIGERATION AND FERMENTATION APPLIANCES AND PRODUCTS.

Judges:—Dr. W. H. Greene, *Chm.*; W. W. Griscom, F. A. Genth, Jr., S. Lloyd Wiegand, J. W. Grant.

The judges have examined "The De La Vergne Refrigerating Machine Company's exhibit," "The Hutchinson Ice Machine," exhibited by the I. P. Morris Co. "The Universal Dry Air Refrigerator," exhibited by the Dickson Manufacturing Company, of Scranton. "The Yaryan Vacuum Distillation Apparatus."

The refrigerating machine of the DE LA VERGNE COMPANY and the HUTCHINSON ICE MACHINE are both in successful operation at the exhibition, and we are unable to make any discrimination as to the awards to which they are entitled. In each machine the cold is produced by the expansion of anhydrous ammonia, which has been previously liquefied by compression and cooling. For the lubrication of the ammonia compressor, the De La Vergne machine employs so large a quantity of oil as to constitute a liquid piston. The Hutchinson machine has a solid piston while sufficient lubrication is not neglected.

The Universal dry air refrigerator is especially adapted for

maintaining a circulation of cold air in chambers in which perishable food is preserved. The air is compressed to about one-fourth its volume, and after cooling is allowed to expand under the normal atmospheric pressure; thus cooled, it passes into the chambers to be refrigerated.

The construction and operation of each of these refrigerating machines is such that an exact comparison of their merits and economies can only be definitely ascertained by a test, for which purpose we recommend that they be referred to the Committee on Science and the Arts, such test being impracticable in the limited time and with the facilities of the exhibition. We believe their operation warrants this recommendation.

(*Each a Silver Medal and reference to the Committee on Science and the Arts.*)

The Yaryan Vacuum Distillation apparatus accomplishes concentration of liquids at low temperatures as in the ordinary vacuum pans, but the evaporation takes place continuously, the liquid flowing through a series of pipes which are jacketed by other pipes carrying steam. The flow of liquid is maintained constant by an automatic pump.

(*A Silver Medal and reference to the Committee on Science and the Arts.*)

GROUP 7.—DRUGS, CHEMICALS, DYE STUFFS, PAINTS, SOAP AND PERFUMERY AND APPLIANCES THEREFOR, AND PHARMACEUTICAL APPARATUS.

Judges:—Thos. S. Wiegand, *Chm.;* F. A. Genth, Jr., D. E. Rice, M. D., H. C. Archibald, M. D., H. Pemberton, S. Lloyd Wiegand.

The judges of group 7, charged with the examination of drugs, chemicals, paints, pharmaceutical apparatus, perfumery, etc., respectfully report that they have examined the articles exhibited, and make the following recommendations:

THE KALION CHEMICAL COMPANY, PHILADELPHIA.

For their exhibit of bichromate of potassium, vanadate of ammonium (meta-vanadate of ammonium), chloride of potassium, etc.

The first two of these are of unusual excellence and make a very fine exhibit. (*A Silver Medal.*)

JAS. M'NAB, PHILADELPHIA.

(U. S. Chemical Company assignees.)

Exhibits a model for the manufacture of sulphuric acid. The patentee states that by means of a supplementary tower, etc., as described, he can remedy in a short time the "sickness" or "paleness" of the acid, which is likely to occur in the last chambers and reduce the consumption of nitrate of soda.

The importance of the sulphuric acid industry induces the judges to call the attention of the Committee on Science and the Arts to this model for a more thorough examination than can be made by this committee.

(*A Silver Medal and reference to the Committee on Science and the Arts.*)

NATHAN BASSETT, OF PHILADELPHIA.

Exhibits a mixer for dry powders, such as paint, flour, etc. It is constructed upon correct principles, and will be of unquestionable advantage. (*Honorable Mention.*)

BARROWS, SAVERY & CO., LIMITED, PHILADELPHIA.

Steam Jacketed Kettle.—These are made of cast iron extremely thin and stiffened by ribs cast with the kettle upon the outer surface and extending radially from the centre of the bottom to the flange, which unites the kettle to the enclosing jacket, which is of similar form.

The large surface both of the ribs and the entire surface of the inner kettle permits rapid absorption of heat from the steam, and the condensed water is guided by the ribs in its descent, so as to keep the surface of the kettle in most effective condition for heating.

By the system of ribbed braces strong kettles of extremely thin metal are made practicable, which heat and cook expeditiously, and are durably enamelled so as to have all the properties of cleanliness and resistance to corrosion found in the Berlin porcelain wares, attended with an increase in capacity impracticable in such ware, and at a cost far below that of copper vessels capable of application to the same uses.

The judges are of the opinion that these vessels are an important addition to laboratory and large culinary operations.

(*A Silver Medal.*)

GROUP 8.—ELECTRIC LIGHTING, MOTORS, DYNAMOS, GENERATORS AND BATTERIES.

Judges:—E. Alex. Scott, *Chm.*, J. Sellers Bancroft, A. B. Wyckoff, Horace W. Sellers, Oberlin Smith, Henry A Rowan.

Of the articles at the Exhibition properly referable to this group, only one was entered for competition—the Edgerton motor, exhibited by

THE EDGERTON MOTOR MANUFACTURING COMPANY, OF PHILADELPHIA.

This company exhibited electric motors of several sizes, from one-twelfth to six horse-power capacity, quite simple in construction. The armature is made in one casting cylindrical in form, split longitudinally into three parts, each of which is supported on the hub or axle by a wide spoke or flange. Upon each of the three flanges is wound a coil of wire, varying in size according to the work required; these coils are connected together at one end of the armature by means of a metal ring, to which an end of each is attached, and the three opposite ends are connected with the commutator. The special advantage claimed for the division into three portions is that there is no dead point in the revolution of the armature, and the form of connection described permits such an adjustment of the coils that the same electrical result will be produced on each of the coils in turn as it reaches the proper point.

The weight of metal in the armature is placed as near the surface of the cylinder as is consistent with strength, so as to bring it near the field. The ends of the cylinder project as far beyond the coils as the thickness of the layers of wire on the coils. The wire is sheltered by the iron and cannot be injured by abrasion on the field. The field is a cylinder, split in half longitudinally, and closely fitting the armature, so that a piece of writing paper could hardly be inserted between them; both the armature and field are turned in a lathe. The winding of the field is upon a series of spools attached to the back of the two parts of the cylinder. The whole is enclosed in an iron shell, to which it is screwed, which supports the bearings and the armature, and forms the yoke of the magnet.

The inventor claims simplicity of construction and durability; that the armature can be run at any speed without displacing the

coils, or permitting them to touch the field; that the metal of the armature is brought nearer to the field; that the counter electromotive force in the wire of the armature is much diminished on account of the wire being further removed from the field.

The judges believe that the claims of the inventor, as above stated, are well sustained by the facts, and that a greater durability and efficiency are thus secured. (*A Silver Medal.*)

GROUP 9.—EDUCATIONAL APPLIANCES

Judges.—Edward Lewis, *Chm.;* Jas. S. Whitney, Lewis M. Haupt.

GEO. J. BAIR, PHILADELPHIA.

The Stenograph, a Machine for Writing Shorthand.—In this machine, the letters are formed by the operation of only five keys. Each key makes a dash in a certain position on the paper, and when two or more keys are struck at once, a great variety of combinations can be made to represent different letters or sounds. It appears to be capable of rapid operation, and for its novelty and usefulness the judges recommend— (*A Bronze Medal.*)

WM. H. TRAVIS, PHILADELPHIA.

Caligraph Type-Writer.—This machine has a double set of keys for large and small type, and every key produces but one letter—the one shown on its face. By this means, shifting keys are avoided, and a saving of time is claimed.

All joints or bearings are provided with adjustable screws, so that lost motion from wear can be taken up as it occurs. A novel feature of the machine is its flat surface roll, which always presents a flat surface to the type, thus giving a clear and full impression of every letter. (*A Bronze Medal.*)

GROUP 10*a*.—FURNITURE.

Judges:—H. R. Heyl, *Chm.;* J. J. Weaver, Samuel Sartain, Isaac Norris, M. D., Fred. Graff.

CLARK BROS. & CO., PHILADELPHIA.

"*Everett*" *Improved Folding or Wardrobe Bedsteads.*—These contain recent improvements upon those previously made under the same inventor's patents. They are very well balanced, easily operated, well ventilated, and in all respects excellent beds, and handsome pieces of furniture. (*A Silver Medal.*)

HALE & KILBURN MANUFACTURING COMPANY, PHILADELPHIA.

A variety of Folding Bedsteads of the Wardrobe and Telescopic Patterns, which are commendable as articles of convenience, practical utility, and as handsome and well made pieces of furniture. A portable reservoir wash-stand, disguised as a writing-desk, shows an ingenuity of combination and beauty of form that renders it very complete, convenient and desirable.

Their display of other furniture and handsome chamber suites is deserving of high commendation for artistic design and superior workmanship. (*A Silver Medal.*)

GATES MANUFACTURING COMPANY, PHILADELPHIA.

A Rotating, Adjustable, Sliding- and Tilting-Top Folding Table.—It is well made, ingeniously designed and very substantial, as well as ornamental. (*A Silver Medal.*)

HENRY GIESE, PHILADELPHIA.

Barber's Chair.—A device applicable to barber's chair, for the elevation and angular adjustment of the back. It is mechanically well designed for the purpose. (*Certificate of Honorable Mention.*)

JOHN RUCH & SONS, PHILADELPHIA.

Specimens of Upholstery, which are excellent, and *Prepared Moth-proof Hair*.

The judges are satisfied as to the reliability of the process as an effectual moth-proofing, but the durability and continued elasticity of the hair so treated can only be determined by a long trial in use.

The exhibit is worthy of commendation for good workmanship, and apparently good results in the direction of preserving upholstery from the ravages of moths. (*A Bronze Medal.*)

SHUPE & NOBLE FURNITURE COMPANY, PHILADELPHIA.

A variety of useful pieces of furniture, notably their "Climax" Folding Bed, which in some of its forms makes an exceedingly light and portable bedstead. It is capable of being advantageously combined with a book-case and writing-desk in a very practical manner, and in some of its forms is very cheap, and a desirable article of furniture. (*A Bronze Medal.*)

HAYNES, SPENCER & CO., RICHMOND, IND.

Several Forms of the *Wootten Writing-desks*, which have an

established and excellent reputation. They are beautiful articles of furniture, well made, very compact, and convenient, and moderate in price. (*A Bronze Medal.*)

LEWIS M. HAUPT, PHILADELPHIA.

Exhibits an arrangement of shelves, closets, drawers, pigeon-holes, adapted for holding books, papers, maps and drawings in a convenient and readily accessible form. The plan is commended for its compactness, convenience and portability.

HARWOOD MANUFACTURING COMPANY, BOSTON, MASS.

Fibre Chair Seatings.—These seats are made of a manilla board, pressed and finished in imitation of leather, and have a handsome appearance. They are claimed to be water-proof and durable and extensively used in the Eastern States.

(*A Certificate of Honorable Mention.*)

GROUP 10 *b* AND *c*.—CARPETS AND UPHOLSTERY AND INTERIOR HOUSE DECORATIONS.

Judges:—S. Lloyd Wiegand, *Chm.*; Coleman Sellers, Jr., Henry B. Riehlé, John A. Wiedersheim.

V. E. ARCHAMBAULT & SON, PHILADELPHIA.

Corticine, manufactured by the Corticine Floor Covering Company, of London, England.

This appears to be * * * an excellent quality of linoleum and as such deserving of commendation.

F. X. BRENNER, PHILADELPHIA.

Self-Tieing Awning.—Consists of a casing or covering containing a very conveniently arranged winding cylinder, bearing the awning and mechanism for turning the same, and also an automatic reel by means of which the awning is readily and securely fastened as closed or extended or in any intermediate position. This is ingenious and useful. (*A Certificate of Honorable Mention.*)

WM. L. WILSON & CO., LIMITED, PHILADELPHIA.

This exhibit embraces several mantels containing enamelled tiles artistically decorated and skilfully jointed together; also, hearths embracing enamelled tiles in mosaic work.

Also a panel illustrating the several species of decoration in encaustic tiles, enamelled tiles, mosaic designs and ceramic art work, embracing the several lines of work executed by this firm.

The enamelled tiles are of English manufacture, and the balance of the work American.

For skilful work and creditable designs— (*A Bronze Medal.*)

BRAINERD & ARMSTRONG, PHILADELPHIA.

Embroidery Silk upon Quills.—This is an article put up by the manufacturers in the form that is best adapted for use by the retail purchaser, and carries with it the label and reputation of the maker to the consumer, conditions which insure the best maintenance of quality.

Victoria Knitting Silk.—The dyes employed in this silk are more permanent than others, withstanding such tests as continuous boiling in water; for uniform excellence of quality both of silk and dye— (*A Silver Medal.*)

J. C. FINN & CO., PHILADELPHIA.

Wall Coverings of Lincrusta Walton, of great beauty of design and perfection of workmanship, manufactured by Fr. Beck & Co., of New York. For richness of design, skilful execution and tasteful display— (*A Silver Medal.*)

A. J. MALONE, PHILADELPHIA.

Excelsior Natural Wood Stains, for imitating hard and fancy woods. These produce excellent imitations, are of easy application and appear to be of good quality and durable.

(*A Certificate of Honorable Mention.*)

SHARPLESS & WATTS, PHILADELPHIA.

Ceramic and Roman Mosaics, of American manufacture, all of excellent quality and skilfully wrought into very rich and elegant designs in mantels, hearths, fire-boards, flues, baths, walls, etc.; also an extremely rich and elaborate exhibit of bronze mantel decorations of unusual excellence and beauty.

The entire exhibit displays skilful work and tasteful designs as well as excellent quality of material. (*A Silver Medal.*)

GROUP 10 *d.*—HATS AND WEARING APPAREL, UMBRELLAS, ETC.

Judges:—John A. Wiedersheim, *Chm.;* Wm. H. Hart, Jr., Wm. H. Thorne.

CHAMBERS & CO., PHILADELPHIA.

The Reliable Umbrella of these exhibitors is meritorious. The stretchers are adapted to prevent the ribs from sticking or catching, and to reduce the space into which the umbrella may be

folded. In opening the umbrella, when the tip cap or other fastening is removed, the ribs are thrown out and away from the stick by the action of the stretchers, thus providing an enlarged space whereby the hand may reach the runner in a most convenient manner without liability to be injured by the points of the ribs. (*A Bronze Medal.*)

JAMES BERNARD WILSON, PHILADELPHIA.

Improvements in Umbrellas.—In this umbrella, the use of the well-known spring catches and slotting of the stick are avoided, and, in lieu thereof, there are employed two catches and a pivoted latch lever. The lever is easily operated to release the runner, and prevents cutting of the thumb, as is usual where the latter presses the wire catches. The face of the lever is adapted to be used as a name-plate, and furnishes a neat finish to the runner.

(*A Bronze Medal.*)

NORCOM L. SEGUIN, PHILADELPHIA.

Improved Self-Closing Umbrellas.—The stick of the handle is connected with the upper catch, and a spring is so arranged that by a simple movement of a pin on the handle, the runner is released and the umbrella closes automatically. The frame is strengthened by scroll-shaped stretchers in such a manner that it is enabled to withstand any strain that may be imparted to it, due to the sudden closing of the umbrella. The judges consider this a useful and valuable improvement in umbrellas.

(*A Bronze Medal.*)

THOMAS R. EVANS, PHILADELPHIA.

Anatomical Boots, Gaiters and Shoes.—The top of the gaiter or shoe is detached in front from the vamp or foot-piece which allows the foot its natural movements. In the boot, an elastic cloth is placed in front, which allows it to be put on and taken off very easily. An accurate fitting of the boot to the ankle-joint is allowed, slipping at the heel prevented, and the ankle-joint retains its natural and unobstructed movements. From the practical demonstration by the exhibitor, the judges believe that the meritorious nature of the improvements warrant—

(*A Bronze Medal.*)

(*To be continued.*)

BOOK NOTICES.

DRAINAGE FOR HEALTH, OR EASY LESSONS IN SANITARY SCIENCE. By Joseph Wilson, M. D. Second Edition. Philadelphia: P. Blakiston, Son & Co.

The first chapter of this work is devoted to the subject of land drainage, and contains the following passage, which refers to one of the most important facts that science is called upon to consider. "In all parts of New England hundreds of people are dying of typhoid fever; a large tract of the city of Boston is now building on made-land nearly as flat as the prairie around Chicago, and in a few years it will probably have to be regulated and rebuilt to get rid of the pestilence. From Maine to Pennsylvania there are undrained fields nearly as bad. All over the country further south, but principally in the Mississippi Valley and in the flat country bordering the ocean, the undrained land is infectious with intermittent fever and other malarial pestilences to such an extent as to destroy many thousands of lives every year; so that in spite of constant immigration extensive tracks of country continue as sparsely populated as ever, with very unhealthy, very unhappy people. Some parts of this desert is the most fertile land in our country, and the most easily cultivated, but for the failure of health among those who undertake to occupy it."

The remedy for this is drainage, and the various methods are fully explained and illustrated by appropriate cuts.

The second chapter contains some brief but pointed remarks on the subject of house drainage, in reference to isolated houses. While the third chapter considers the subject of the drainage of cities, which includes the details of the so-called "modern conveniences," which it must be admitted, have, within the last few years, been brought to a perfection that leaves little to be desired in the way of improvement. Yet it is a lamentable fact that the water-carriage system, with all its advantages, involves the necessity of wasting valuable manure and polluting the rivers in a most disgusting and dangerous manner; for, as the writer points out, minute organisms may thus be introduced into the stomach, which may produce the most serious results. This statement is rendered very impressive by reference to the young of the tape-worm, which may penetrate to vital parts of the body and produce death.

We reviewed the first edition of this work in the February issue of the JOURNAL in the year 1881, and do not observe that anything of value has been added to this edition. W. B. C.

CLASS BOOK OF GEOLOGY. By Archibald Geikie, LL.D., F.R.S., Director-General of the Geological Surveys of the United Kingdom, etc. London: MacMillan & Co. 1886.

This book, as stated in the preface, completes a series commenced while the author occupied the Chair of Geology in the University of Edinburgh, now filled by his brother. One of the best features of these books is that their author was sufficiently in earnest, in producing them, not to be turned from his purpose by his largely extended field of labor consequent upon

taking active charge of the Survey of the British Isles, relinquished by Ramsay. The present book is a small octavo of 478 pages, with an appendix of twenty pages and an index of eighteen pages. The wood-cut illustrations are made by Messrs. J. D. Cooper and M. Lacour, presumably from original designs by the author (though he does not say so) and are in general fair, and in some cases very good, for the purposes of illustration; though they cannot be said to be quite abreast of the best art of illustrated designs, unless some of the representations of crystals and rocks be excepted from this statement. The author, of course, presents a picture of Fingal's Cave (page 219), without which no English text-book of geology would be complete, but he avoids the errors so humorously alluded to in the *Engineering and Mining Journal* last year, by taking his point of view at such a distance that the observer is unable to say whether the "whole back of the cave has been taken out as useless" or not. The advantage that this may have, however, is compensated by a lack of definition of the striking columnar masses.

This lack of definition is strikingly shown on other illustrations, and notably on that of "Schistose Structure," on page 194, which represents a block, which might as well be a piece of agate or variegated marble as that for which it stands.

On the other hand, the group of calcite (Iceland spar) crystals, on page 166, is an admirable piece of wood cutting: but even here the original design, though doubtless quite true to nature, might have been made at such an angle to the visual ray as to avoid the deception of cubical cleavage. The illustration, on page 142, of the "outline of a volcanic neck," has the fault, for a book of this kind, that it is not characteristic, though doubtless Dr. Geikie could tell us just where this phenomenon could be observed. It is nothing but a very ordinary little rounded hill, suggesting in its outline a granite or heavy bedded gneiss nucleus. It is difficult to understand, even in his vertical section, how the line of demarcation between the sedimentary exterior and the volcanic core should be entirely unmarked by any topographical feature. On page 125, we are told that "crust" is used "without implying any theory as to the nature of the interior of the globe;" and, on page 126, one reads that "it is quite certain that the interior of the globe must be intensely hot."

The book is a useful one for beginners in geology, and derives much of its value from the author's lucid and simple English style. P. F.

THE MANUFACTURE, CONSUMPTION AND PRODUCTION OF IRON, STEEL AND COAL IN THE DOMINION OF CANADA, WITH SOME NOTES ON THE MANUFACTURE OF IRON AND ON THE IRON TRADE IN OTHER COUNTRIES. By James Herbert Bartlett. Montreal: Dawson Brothers. 1885.

This is a very interesting and complete as well as convenient table of statistics which is chiefly unfortunate in its unintelligible title. The consumption and production of coal and the manufacture of steel and iron are economical data, which more than any others fix the commercial status of the nation, but what is one to understand. The publisher of the volume, Mr. Dawson (himself an author and a purist), is one of the last persons one would have suspected of printing such a sentence. It must be said, however, that

the manufacture of coal, of crude petroleum, rock salt and the like are terms not unfrequently met with. This defect in the title, however, does not prevent the volume from being one of great statistical value to the economist, and especially to the iron manufacturer.

The patriotic author deplores the condition of the iron industry in Canada, and seeks to prove that she has the ore, she has the coal, and she has the talent too (to alter slightly the popular Jingo song in Disraeli's time). This view has also the merit of being justified by the facts.

The introduction forms the first chapter. The second is devoted to the St. Maurice forges; the third to the early enterprises in Ontario; the fourth to iron smelting in New Brunswick. Chapter V, on the manufacture of iron in Nova Scotia, consists largely of tabular statements of the "domestic production of iron, steel and coal." All this part of the book (except the introduction) has been read as a paper before the Institute of Mining Engineers at its Halifax meeting last fall.

The remaining chapters, VI, VII and VIII, deal respectively with (Chapter VI) iron ores, fluxes and commercial classification; (Chapter VII) improvements in the processes of manufacture, and (Chapter VIII) how other countries have fostered the iron industry. These very broad subjects are very lightly touched upon, except the last. In the conclusion, the writer favors specific and not *ad valorem* duties. He thinks the figures of the Custom House show that Canada has a non-protective tariff, and that she is constantly draining herself of large amounts of money, in order to pay for what she ought to produce within her own borders, and she has not even the consolation of getting iron any cheaper than it can be got in the United States.

The appendix of twelve pages is devoted to a comparative statement of the import duties. F.

THE MATERIALS OF CONSTRUCTION. By Robert H. Thurston, M. A., Doc. Eng. New York: John Wiley & Sons.

This second work by Professor Thurston is an abridgment of his large one. We abstract from the preface the following, which exhibits the scope of the work: The essential parts only of the earlier treatise have been retained. The volume thus constructed is of manageable size, is of such comparatively low cost that it can probably be brought into use in any technical school; and yet it contains enough of the matter collected in the extended work to furnish a basis for the course of instruction and machine design taught in the most elaborate course yet adopted in any such schools. The origin, nature, method of preparation, and the useful properties of all the common and so-called useful metals, and their strength, elasticity and other qualities essential to their introduction into the various constructions, which the engineer is called upon to build or to inspect, are treated of at considerable length, and the influence of the more common conditions affecting them is studied. C. A. E.

TABLES FOR CALCULATING EARTHWORKS. By John R. Hudson, C. E. New York : John Wiley & Sons.

These tables are apparently founded upon the method of Henck given in his pocket-book, of which they endeavor to be a simplication. It is rather difficult to pronounce upon the superiority of any method of calculating earthworks; so much depends upon that to which an engineer has habituated himself. Custom on this point seems to guide the preference of every practitioner. Again, some engineers appear to regard all refinement as inapplicable to the calculation of earthworks ; in their opinion the contents are simply a rather rude approximation, necessarily so from the irregularities of the ground being so sudden in many instances. Hence they average the end sections and multiply the result by their distance apart. But some strong arguments may be advanced in support of the opposite course. Hudson's tables may prove of interest and use, and are certainly entitled to as much consideration as any others.

C. A. E.

A TREATISE ON THE MANUFACTURE OF SOAP AND CANDLES, LUBRICANTS AND GLYCERINE. By Wm. Lant Carpenter, B. A., B. Sc. E. & F. N. Spon. 1885.

This treatise is an octavo of some 350 pages, with numerous illustrations, good print and bad binding. The author, as he states in his preface, has been engaged in these industries for several years, and is therefore able to speak upon the practical points of many of the subjects described, as one having authority.

There are a number of tables of specific gravity, freezing points, etc., also the specifications of over 100 patents. Many of these have been issued within late years; some as late even as 1884. This same characteristic of being "up to date," appears throughout the volume, in references to the recent numbers of scientific journals, etc.

The book is exhaustively written, and proper attention is given to the scientific principles involved. Sometimes the elaboration is carried too far; as in the description of Leblanc's process of manufacturing soda ash. If there be a subject in technical chemistry that has been thoroughly studied and written upon, it is this same Leblanc process. And to go over the ground again is only a waste of paper and printer's ink.

The book is divided as follows : Eight chapters are given to the manufacture of soap, one to lubricating oils, three to candles, stearine, etc., and one to glycerine. And, last, but not least, the author closes with a good index.

H. P., JR.

A GUIDE TO SANITARY HOUSE INSPECTION. By William Paul Gerhard, C. E. New York : John Wiley & Sons. 1885.

The principal aim of this work, as stated in the prefaces, is to broadly outline the main features of sanitary house inspection for the guidance of the householder. It is not designed to be a work on sanitary appliances and construction, but as a directory of the points requiring attention. We heartily endorse the following passage. "No prudent man would think of buying a

house without carefully examining the title of the property; and it is now regarded, in real estate transactions, as a necessary expenditure to pay competent lawyers for services rendered in securing evidence as to the correctness of the title of a property before concluding a bargain. But not one out of a hundred or more purchasers would deem it of sufficient importance to secure a certificate from an expert that the house is built in accordance with sanitary rules and regulations. And yet, if the buyer intends to make the house his future residence, his own health, and that of his family and household, will depend upon its cleanliness and salubriousness. The same remarks apply, with equal force, to houses for rent, located in the city, in the suburbs, or in the country."

In speaking of country houses he says: "A public supply delivering water to all habitations in pressure-conduits or street-mains, is seldom available; and drinking water must usually be drawn by buckets or pumps from a well on the premises, sunk to only a shallow depth, and often liable to be contaminated from surface washings, or by careless dipping into it of unclean vessels. Driven wells are not so liable to surface contamination; yet even they may be poisoned by leakage of sewage, unless sunk to a very great depth, and penetrating below some impervious stratum. It sounds like a truism to say that wells supplying drinking water must be most scrupulously watched, and kept free from contamination; yet how seldom is proper care bestowed upon this matter! The drain which carries the liquid wastes from the house to a cesspool often passes near the well; and unless the pipes are laid with unusual care and forethought, by experienced workmen, the imperfect and often uncemented joints and broken pipes allow the slop water to leak into the soil, from which it passes by filtration into the well.

"But the most frequent and most dangerous causes of the contamination of wells are the leaching cesspool (that vast receptacle of decomposing organic matter from the household), and the privy, both generally located, on account of convenience and economy, very near the house."

The work is printed in large type and is well adapted to fulfil its mission; being a creditable addition to this class of literature. W. B. C.

HEALTHY FOUNDATIONS FOR HOUSES, with fifty-one illustrations. By Glenn Brown. New York: D. Van Nostrand.

This is one of the numerous reprints issued by this establishment. The following passage explains the scope of the work: "To obtain healthy foundations, it is necessary to select or so treat the building site that it will be free or protected from vegetable and animal matter in the subsoil, which, in the process of decay, would generate poisonous gases; it must also be free, naturally or artificially, from dampness—*i. e.*, there must be no springs, watercourses or standing water within the area of ground covered by the building.

"It being an accepted fact that damp and polluted soils are unhealthy when used as foundations, it only comes within the province of a treatise of this kind to show how buildings can be protected from the evils which would be produced."

A detailed description of the various methods of constructing and draining foundations is given, with reference to those adopted by the Greeks and Romans.

The work is one which forms a desirable addition to the extensive list of publications of its class. W. B. C.

LIST OF BOOKS.

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New York. Board of Commissioners of Central Park. Fourteenth Annual Report, 1870. New York. [This completes this series. The Board having been abolished and the Department of Public Parks created, the first report of which is dated 1871 (May).—E. H.]

New York. Department of Public Parks. First Annual Report of Board of Commissioners. 1871.

New York. Documents relating to the Colonial History of. Vol. 14. Albany, 1883. Presented by the New York State Library.

New York State Agricultural Society. Transactions 1877–82. Albany, 1884. Annual Reports for 1883 and 1884. Albany, 1884 and 1885. Presented by the Society.

New York State Board of Health. First to Fourth Annual Reports. 1880–1884. Albany, 1881–1885. Presented by the Board.

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Neylert, A. P. Notes on the Opium Habit. New York, 1885. Presented by the Author.

Norfolk, Va. Messages of the Mayor for 1883–1884. Presented by the Mayor.

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Observations made at Various Stations in India, for June, July and August, 1884. Presented by the Meteorological Dept., Govt. of India.

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Pennsylvania. Annual Reports of the State Treasurer for 1883 and 1884. Harrisburg. Presented by the State Treasurer.

Pennsylvania. Annual Reports of the State Treasurer on the Finances for 1845-47, 1849, 1850, 1853, 1854, 1856, 1858, 1860, 1862. Harrisburg.

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Philadelphia County Prison. Annual Reports of the Inspectors. Third, Seventh and Thirteenth to Twentieth inclusive. [This completes this series of reports to 1867, after which they are found in reports of Board of Public Charities.—E. H.]

Philadelphia Directory for 1816. By James Robinson.
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Sanitary Gleanings. Vol. 1. Philadelphia, 1884–85.

Sartain, John. On the Antique Painting in Encaustic of Cleopatra. Discovered in 1818. Philadelphia. G. Gebbie & Co. 1885. Presented by the Author.

[This work, dedicated to the Baron de Benneval, of Sorrento, Italy, by his friend, Mr. Sartain, contains, among other illustrations, three fine steel plate engravings, distributed as follows: Frontispiece, "Cleopatra Receiving her Death from the Bite of an Asp," after the original at Sorrento; (2.) "The Muse of Cortona," and (3.) the "First Meeting of Anthony and Cleopatra." Also, a letter of M. Le Marquis Cosimo Ridolfi to the Professor Petrini, containing a report of the results of a chemical examination of the materials used in an antique painting in Encaustic, representing Cleopatra. Translated from the "Autologia." Florence, Tuscany, 1822. A translation from the supplements to the "Allgemeine Zeitung," Augsburg, 1822, entitled "An Inquiry into the Art of Painting in Encaustic, as practiced by the Ancients, and on the Antique picture of Cleopatra, in possession of the Baron de Benneval, at Sorrento," by Dr. R. Schoener, followed by a description of "A Forgotten Picture," by Michael Iwanoff, special correspondent to the journal "Nouveau Temps," of St. Petersburg, and a note of the fact that the steel engravings that embellish the book is the work of the distinguished Philadelphia artist, the author.—E. H.]

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// JOURNAL

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THE EFFECT OF THE INERTIA OF THE RECIPROCATING PARTS IN MODIFYING THE FORCE TRANSMITTED TO THE CRANK PIN.*

BY FRANCIS E. JACKSON, M. E.

The question concerning the inertia of the reciprocating parts of the steam engine has only quite recently been considered.

Mr. Charles T. Porter was the first, so far as I know, to recognize the fact that this inertia, in high-speed engines, modified the pressure on the crank pin to a considerable extent. The demonstration was published by Mr. Porter, in his work on *Richards' Steam Indicator*.

Since the above fact was pointed out, there has been a difference of opinion among engineers as to the advisability of increasing the inertia of the parts by making them heavier than is necessary for strength.

* Graduation Thesis; communicated by DE VOLSON WOOD, Professor of Engineering at Stevens Institute of Technology.

If it is an advantage to have the reciprocating parts heavy, the proper distribution of this weight must be considered.

It is now intended to show the effects of placing two different weights in cross-head and piston of an engine running under the same conditions in both cases; and also the effects of placing equal weights first entirely in the cross-head and then in the connecting rod. The effects sought in any case are a uniform tangential effort on the crank pin and the possibility of making a perfect balance.

The exact formulæ for general cases are first deduced, then simplified by neglecting terms which do not affect the results materially and applied to particular cases.

In this investigation the following conditions are assumed:

The engine works without friction;

The angular velocity of the crank is uniform;

The areas of the piston on both ends are equal;

Also, the influence of gravity is neglected.

The inertia of the piston, piston rod and cross head is overcome by the steam directly during the first part of either stroke; during the latter part, the force due to the inertia acts directly with the steam. To find the equivalent steam pressure per unit area of piston, it is only necessary to find the acceleration, when, the piston area and weight of parts being known, the force of acceleration can be found.

Let $F =$ the force of acceleration of piston, piston rod, and cross-head;

$s =$ distance passed through at any point of stroke;

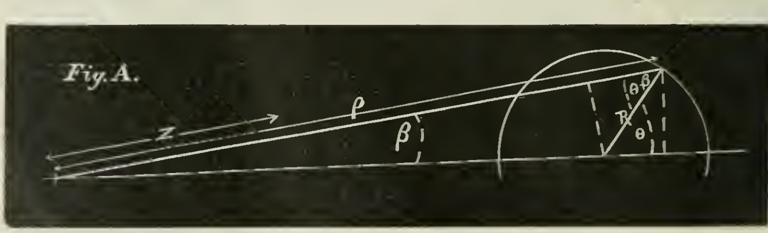
$R =$ length of crank;

$\rho =$ length of connecting rod;

$\theta =$ the crank angle, and

$\beta =$ connecting-rod angle.

Fig. A.



Then

$$s = R \operatorname{vers} \theta - \rho \operatorname{vers} \beta$$

$$d s = R \sin \theta \, d \theta - \rho \sin \beta \, d \beta$$

$$R \sin \theta = \rho \sin \beta \,; \; \therefore \sin \beta = \frac{R \sin \theta}{\rho}$$

$$\cos \beta = \sqrt{1 - \frac{R^2 \sin^2 \theta}{\rho^2}} = \frac{1}{\rho} \sqrt{1 - R^2 \sin^2 \theta}$$

$$\cos \beta \, d \beta = \frac{R \cos \theta \, d \theta}{\rho} \,; \quad d \beta = \frac{R \cos \theta \, d \theta}{\sqrt{\rho^2 - R^2 \sin^2 \theta}}$$

$$d s = R \sin \theta \, d \theta - \frac{R^2 \sin \theta \cos \theta \, d \theta}{\sqrt{\rho^2 - R^2 \sin^2 \theta}}$$

$$\frac{d^2 s}{d \theta^2} = R \cos \theta - R^2 \left[\frac{\cos^2 \theta - \sin^2 \theta}{\sqrt{\rho^2 - R^2 \sin^2 \theta}} + \frac{R^2 \sin^2 \theta \cos^2 \theta}{(\rho^2 - R^2 \sin^2 \theta)^{\frac{3}{2}}} \right]$$

$$= R \cos \theta - R^2 \left[\frac{\cos 2 \theta}{\sqrt{\rho^2 - R^2 \sin^2 \theta}} + \frac{R^2 \sin^2 (2 \theta)}{4 (\rho^2 - R^2 \sin^2 \theta)^{\frac{3}{2}}} \right]$$

$$\frac{d^2 s}{d t^2} = \frac{d^2 s}{d \theta^2} \omega^2 = \frac{d^2 s}{d \theta^2} \left(\frac{2 \pi N}{t} \right)^2 = \frac{39{\cdot}48 \, N^2}{t^2} \cdot \frac{d^2 s}{d \theta^2}$$

Then if W = the weight of the piston and piston rod, then

$$F = \frac{W}{g} \cdot \frac{39{\cdot}48 \, N^2}{t^2} \cdot \frac{d^2 s}{d \theta^2}$$

$$= \frac{W}{g} \cdot \frac{39{\cdot}48 \, N^2}{t^2} R \left[\cos \theta - R \left(\frac{\cos 2 \theta}{\sqrt{\rho^2 - R^2 \sin^2 \theta}} + \frac{R^2 \sin^2 (2 \theta)}{4 (\rho^2 - R^2 \sin^2 \theta)^{\frac{3}{2}}} \right) \right] \tag{A}$$

THE CONNECTING ROD.

The motion of the connecting rod is the result of two motions, one of translation with the cross-head, and one of rotation around the cross-head pin.

The longitudinal acceleration is produced by two forces acting, one at each end of the rod (through the centres of the cross-head and crank pins), the magnitudes of the forces varying inversely as the distances of their points of application from the centre of gravity of the rod. The sum of these two forces must necessarily equal the total amount of force if applied directly at the centre of gravity.

Let f'' = the force necessary to be applied at the crank pin parallel to the piston rod to produce the longitudinal acceleration;

F' = the force necessary to be applied at the cross-head in the line of the piston rod, so that this force and f'' would produce the longitudinal acceleration of the connecting rod;

F'' = the force applied at the piston to produce the longitudinal effort f''.

Then it is readily seen from *Fig. A* that, by equating the moments of $F'' \sec \beta$ and f'', the total pressure on the piston due to the longitudinal acceleration alone

$$= F' + F'' = F' + \frac{f'' \sin \theta \cos \beta}{\sin (\theta - \beta)} \qquad \text{(B)}$$

where

$$F'' \sec \beta . \quad R \sin (\theta - \beta) = f'' . \quad R \sin \theta$$

$(F' + f'')$ is determined exactly as F.

The position of the centre of gravity being known, F' and f'' are known, and consequently $F' + F''$ becomes known.

The motion of rotation around the cross-head pin may be resolved into two motions—one longitudinal, the other lateral; in each case the forces producing the motions are applied at the crank pin centre and act in the direction of the motion produced.

To determine these forces, the form of the rod must be known, or the radius of gyration with reference to the cross-head pin as an axis must be known.

In *Fig. A* let z = the distance of any point in the length of the rod, measured from the cross-head; and x = the distance passed through longitudinally, due to the rotation.

Then, leaving out intermediate steps:

$$\rho \sin \beta = R \sin \theta$$

$$x = z \text{ vers } \beta$$

Differentiating

$$\frac{dx}{d\theta} = z \frac{R^2 \sin \theta \cos \theta}{\rho \sqrt{\rho^2 - R^2 \sin^2 \theta}}$$

$$\frac{d^2 x}{d \theta^2} = \frac{z R^2}{\rho} \left[\frac{\cos 2 \theta}{\sqrt{\rho^2 - R^2 \sin^2 \theta}} + \frac{R^2 \sin^2 2 \theta}{4 (\rho^2 - R^2 \sin^2 \theta)^{\frac{3}{2}}} \right]$$

$$\frac{d^2 x}{d t^2} = \frac{d^2 x}{d \theta^2} \omega^2$$

will be the acceleration parallel to the piston rod for any point, where

$$\omega = \frac{2 \pi N}{t}$$

Suppose, the radius of gyration equals z. The force applied at distance $\rho = \frac{z}{\rho} \times$ by what it would be if applied at distance z.

Let $f_1 =$ longitudinal component of the force applied at the crank-end of the rod, producing rotation;

$F_1 =$ the equivalent force on the piston.

Then

$$f_1 = \frac{W_1}{g} \cdot \frac{z}{\rho} \cdot \frac{d^2 x}{d \theta^2} \cdot \omega^2$$

$$= \frac{W_1}{g} \cdot \left(\frac{2 \pi N}{t}\right)^2 \cdot \frac{z^2}{\rho^2} \cdot R^2 \left[\frac{\cos 2 \theta}{\sqrt{\rho^2 - R^2 \sin^2 \theta}} + \frac{R^2 \sin^2 (2 \theta)}{4(\rho^2 - R^2 \sin^2 \theta)^{\frac{3}{2}}}\right] \qquad \text{(C)}$$

$$F_1 = \frac{f_1 \sqrt{\rho^2 - R^2 \sin^2 \theta}}{\sqrt{\rho^2 - R^2 \sin^2 \theta} - R \cos \theta} \qquad \text{(D)}$$

Proceeding as above, let y equal the distance passed through laterally by any point in the rod.

Then

$$y = z \sin \beta = z \frac{R}{\rho} \sin \theta$$

$$d y = \frac{z R}{\rho} \cos \theta . d \theta$$

$$\frac{d^2 y}{d \theta^2} = - \frac{z R}{\rho} \sin \theta,$$

$$\frac{d^2 y}{d t^2} = \frac{d^2 y}{d \theta^2} \omega^2$$

Let $f_2 =$ the lateral component of the force applied at the arm ρ, producing rotation;

$F_2 =$ the corresponding force on the piston;

$z =$ the radius of gyration.

$$f_2 = \frac{W_1}{g} \cdot \frac{z}{\rho} \cdot \frac{d^2 y}{d \theta^2} \omega^2 = - \frac{W_1}{g} \cdot \left(\frac{2 \pi N}{t}\right)^2 \cdot \frac{z^2}{\rho^2} . R \sin \theta \qquad \text{(E)}$$

$$F_2 = \frac{f_2 \cos \theta \cos \beta}{\sin (\theta - \beta)} = \frac{f_2 \cos \theta \sqrt{\rho^2 - R^2 \sin^2 \theta}}{\sin \theta (\sqrt{\rho^2 - R^2 \sin^2 \theta} - R \cos \theta)} \qquad \text{(F)}$$

SIMPLIFICATION OF THE PRECEDING FORMULÆ FOR ORDINARY CASES.

In equation (A), the following equations are practically true,

the connecting rod being more than four times the crank radius:

$$\sqrt{\rho^2 - R^2 \sin^2 \theta} = \rho$$

(error less than five per cent. in extreme cases).

$$\frac{R^2 \sin^2 (2\,\theta)}{4\,(\rho^2 - R^2 \sin^2 \theta)^{\frac{3}{2}}} = 0$$

(because very small compared with the preceding terms).

And equation (A) becomes

$$F = W\,.\,1{\cdot}22\,\frac{N^2}{t^2}\,.\,R\left(\cos\theta - \frac{R\cos 2\,\theta}{\rho}\right). \qquad \text{(a)}$$

F′ + F″ SIMPLIFIED.

From equation (B),

$$F'' = \frac{f''\sin\theta\cos\beta}{\sin(\theta-\beta)} = \frac{f''\sqrt{\rho^2 - R^2\sin^2\theta}\,.\,\sin\theta}{\sin\theta\,(\sqrt{\rho^2 - R^2\sin^2\theta} - R\cos\theta)}$$

$$= \frac{f''\,\rho}{\rho - R\cos\theta}\ \text{(nearly).} \qquad \text{(b)}$$

$$f'' = \frac{z}{\rho}\,(F' + f'')$$

$$F' = constant - f''.$$

$F' + f''$ is found by the same formula as F, after making the necessary corrections for weight.

This process is long and tedious; a sufficiently near approximation is reached when both forces, F' and f'', are supposed to be applied at the piston directly. That is to say, make $F'' = f''$. With these conditions, F' and F'' may be included in the value of F by making $W =$ the whole weight of reciprocating parts including the connecting rod.

Equation (C) becomes

$$f_1 = 1{\cdot}22\ W\,.\,\frac{N^2}{t^2}\,.\,\frac{z^2}{\rho^2}\ \frac{R^2\cos 2\,\theta}{\rho}, \qquad \text{(c)}$$

and (D) becomes

$$F_1 = 1{\cdot}22\,W\,.\,\frac{N^2}{t^2}\,.\,\frac{z^2}{\rho^2}\,.\,\frac{R^2\cos 2\,\theta}{\rho - R\cos\theta} \qquad \text{(d)}$$

and (E),

$$f_2 = -\,1{\cdot}22\ W\,.\,\frac{N^2}{t^2}\,.\,\frac{z^2}{\rho^2}\,.\,R\sin\theta \qquad \text{(e)}$$

and (F) becomes

$$F_2 = -\ 1{\cdot}22\ W . \frac{N^2}{t^2} . \frac{z^2}{\rho^2} . \frac{R\,\rho \cos\theta}{\rho - R\cos\theta} \qquad \text{(f)}$$

The algebraic sum of these forces $F + F' + F'' + F_1 + F_2 =$ the equivalent force, exerted at the piston, due to the acceleration.

When this sum is positive, work is being done by the steam on the reciprocating parts; when negative, this work is being given out by these parts, the driving point being the crank pin.

The above summation is the equivalent pressure on the whole piston area; in practice, it is generally necessary to find the pressure per unit area, as steam pressures are always given in pounds per unit area.

THE PRECEDING FORMULÆ APPLIED TO THE CASE OF THE 11½ X 20 INCHES PORTER-ALLEN ENGINE.

This engine was built to be run at 230 revolutions per minute.

There are two cases: in one case, the piston and cross head weighs 186 pounds, and in the other 128 pounds. The weight of the connecting rod is the same in both cases, being 124 pounds.

The connecting rod, between the centres of crank and cross-head pins, is six cranks in length, the crank being ten inches long.

The radius of gyration is found to be about $\frac{7}{10}\rho$, which gives

$$z^2 = \tfrac{1}{2}\rho^2 \text{ nearly } \therefore \frac{z^2}{\rho^2} = \tfrac{1}{2}$$

In this case, the ratio $\dfrac{R}{\rho} = \frac{1}{6}$ is so small that, practically, $F'' = f''$ and the forces F' and F'' may be included in F (Eq. a), by making $W = 310$ pounds and 252 pounds in the two different cases as has been done below.

For $W = 310$ pounds.

$$F = 1{\cdot}22 \times \frac{310}{103{\cdot}5} \times \frac{(230)^2}{(60)^2} . \tfrac{5}{6}\left(\cos\theta - \frac{\frac{5}{6}\cos 2\,\theta}{\frac{6 \times 5}{6}}\right),$$

the second number of the equation being divided by the piston area ($\pi\, r^2 = 103{\cdot}5$)

$$= 7{\cdot}5\ (6 \cos\theta - \cos 2\,\theta) \text{ lbs. per square inch.} \qquad (1)$$

For $W = 252$ pounds.

$$F = 6{\cdot}09\ (6\cos\theta - \cos 2\,\theta). \qquad (2)$$

$$f_1 = 1{\cdot}22 \times \frac{124}{103{\cdot}5} \times \frac{(230)^2}{(60)^2} . \frac{1}{2} . \frac{25}{36} . \frac{\cos 2\,\theta}{\frac{6 \times 5}{6}} = 1{\cdot}5 \cos 2\,\theta \quad (3)$$

$$F_1 = \frac{9 \cos 2\theta}{6 - \cos\theta}. \tag{4}$$

$$f_2 = - 8{\cdot}97 \sin\theta. \tag{5}$$

$$F_2 = - \frac{269 \cos\theta}{30 - 5\cos\theta} = \frac{53{\cdot}8 \cos\theta}{6 - \cos\theta}. \tag{6}$$

That portion of F due to the inertia of the connecting rod

$$= F' + F'' = \frac{124}{310} \times 7{\cdot}5\,(6 \cos\theta - \cos 2\theta)\,\text{(approximately)}$$

$$= 3\,(6 \cos\theta - \cos 2\theta). \tag{7}$$

The effort in the direction of motion of the crank pin, for any part of the stroke equals the pressure on the piston $\times \sec\beta \sin(\theta - \beta)$.

To prove that there is no work lost: Suppose the pressure $(= P)$ constant;

$$P \sec\beta \sin(\theta - \beta) = P\left(\sin\theta - \frac{R \sin\theta \cos\theta}{\sqrt{\rho^2 - R^2 \sin^2\theta}}\right);$$

Multiplying by $R\,d\,\theta$ and integrating;

$$P R \int_0^\pi \sin\theta\, d\theta - P R^2 \int_0^\pi \frac{\sin\theta \cos\theta\, d\theta}{\sqrt{\rho^2 - R^2 \sin^2\theta}}$$

$$= P R \Big[- \cos\theta \Big]_0^\pi - P R \left[\left(\frac{\rho^2}{R^2} - \sin^2\theta \right)^{\frac{1}{2}} \right]_0^\pi$$

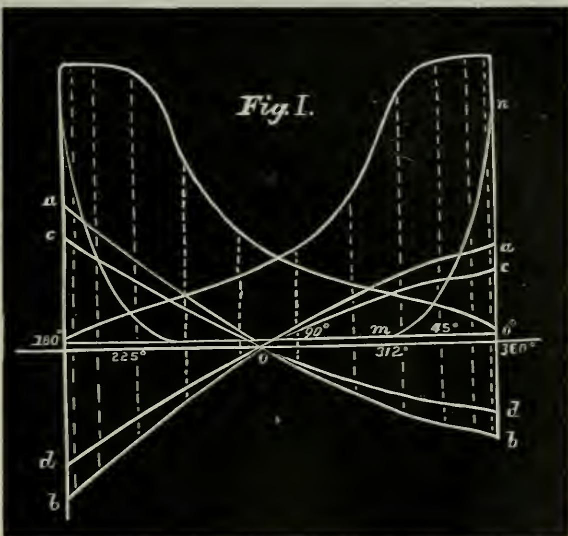
$= 2\,P R = P\,2\,R$, which equals the work done by the steam.

	0°	15°	30°	45°	60°	75°	90°	105°	120°	135°	150°	165°	180°	
F	37·5	36·7	35·2	31·8	26·3	18·2	7·5	—5·2	—18·8	—31·8	—42·7	—50·	—52·5	$W = 310$ lbs.
f_1	1·5	1·3	·75	0·	— ·75	— 1·3	— 1·5	—1·3	— ·75	0·	·75	1·3	1·5	
F_1	1·8	1·6	·88	0·	— ·82	— 1·4	— 1·5	—1·25	— 6·9	0·	·66	1·12	1·29	
f_2	0·	— 2·3	— 4·5	— 6·3	— 7·8	— 8·7	— 9·	—8·7	— 7·8	— 6·3	— 4·5	— 2·3	0·	
F_2	—10·8	—10·3	— 9·8	— 7·2	— 4·9	— 2·4	0·	2·2	4·1	5·7	6·8	7·5	7·7	
$F + F_1 + F_2$	28·5	27 9	26·3	24·6	20·5	14·4	6	—4·2	—15·3	—26·1	—35·3	—41·4	—43·5	
$F' + F''$	15·	14·7	14·1	12·7	10·5	7·3	3·	—1·3	— 7·5	—12·7	—17·1	—20·	—21·	
F	30·5	29·8	28·6	25·8	21·3	14·8	6·1	—4·2	—15·2	—25·8	—34·7	—40·6	—42·7	$W = 252$ lbs.
$F + F_1 + F_2$	21·5	21·	19·7	18·6	15·6	11·	4·6	—3·2	—11·8	—20·1	—27·3	—32·	—33·7	
$\sec\beta \sin(\theta - \beta)$	0·	·22	·43	·62	·79	·92	1·	1·	·94	·79	·57	·30	·0	

The foregoing table has been computed from equations (1) to (7) for the two cases.

GRAPHICAL REPRESENTATION.

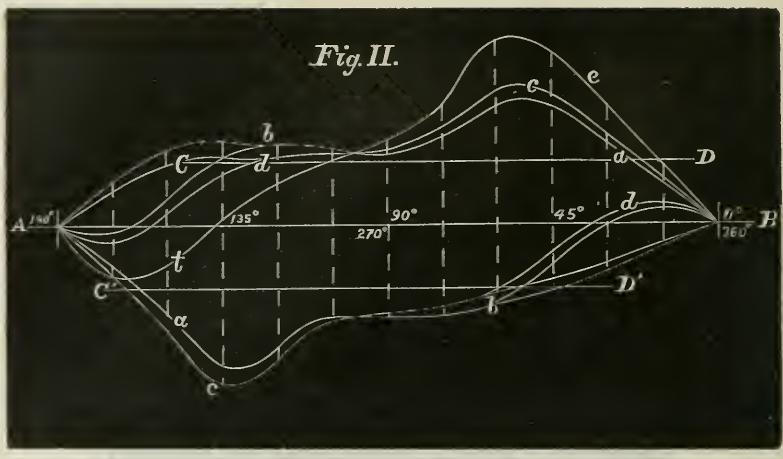
In *Fig. 1*, are represented copies of an indicator diagram, taken from one of the Porter-Allen engines, before described, and also curved lines for each case under consideration, the ordinates of which, measured from the atmospheric line, are proportional to the forces of acceleration, or to $F + F_1 + F_2$ in the preceding table. The ordinates, both on the indicator diagram and to the acceleration curves are drawn to a scale on which an inch represents thirty-two pounds.



The lines $a\ b$ are the acceleration curves for the greater weight, and $c\ d$ for the lesser weight.

The effective pressure on the piston equals the pressure in cylinder, minus back pressure, minus the force of acceleration. It is readily seen that this pressure becomes negative soon after the compression line $m\ n$ passes the acceleration line $o\ a$.

In *Fig. II*, the ordinates to the curves from the line $A\ B$ are drawn to the same scale as above, and represent the tangential effort for the forward and return stroke. The line $a\ b$ is for the heavier weight, and $c\ d$ for the lighter one, as in *Fig. I*; the ordinates to the curved line $e\ f$ represent what the efforts would be if



the reciprocating parts were destitute of weight. If the tangential effort were constant throughout the stroke, the work done being the same, the ordinates would necessarily be terminated by the straight lines $C D$ and $C' D'$. The portion of the area of these curves which is outside the area enclosed by the rectangles thus formed, expressed in foot-pounds, is the ΔE referred to by Rankine in his formula for fly wheels.* The area of each of these rectangles which equals the area of the curves for one-half of a revolution, expressed in foot-pounds, equals $\int p ds$.

For no weight in the reciprocating parts, we would have during the forward stroke $\frac{\Delta E}{\int p\, d s} = \cdot 49$

For smaller weight (252 pounds).

Forward stroke $\frac{\Delta E}{\int p\, d s} = \cdot 29.$

Backward stroke $\frac{\Delta E}{\int p\, d s} = 374.$

For heavier weight (310 pounds)

Forward stroke $\frac{\Delta E}{\int p\, d s} = \cdot 253.$

Backward stroke $\frac{\Delta E}{\int p\, d s} = \cdot 325.$

Thus it is seen that, with this indicator diagram and number of

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* *Rankine's Applied Mechanics*, p. 263.

revolutions, ΔE decreases with the increase of weight of the reciprocating parts.

On making a comparison of the various formulæ for fly wheels given by different manufacturers, it is found that they all give about three or four times the weight found by the theoretical formula. That cushioning affects the uniformity of the tangential effort to a considerable extent is seen by comparing the actual curve with the curve as it would be if the back pressure were constant throughout the stroke. With cushioning, the curve crosses the zero line, and the ordinate becomes negative.

TO COMPARE THE RESULTS OF PLACING 300 POUNDS ENTIRELY IN THE CROSS-HEAD, AND THEN THE SAME WEIGHT ENTIRELY IN THE CONNECTING ROD.

The engine considered is the same as the one before described, excepting that in the first case the connecting rod is supposed to have no weight, and in the second case the piston and cross head have no weight.

In the first case the only force to be considered in finding the ordinates to the acceleration curve is F, equation (a).

$$F = 1{\cdot}22 \times \frac{300}{103{\cdot}5} \times \frac{(320)^2}{(60)^2} \cdot \frac{5}{6} \left(\cos\theta - \frac{\frac{5}{6}\cos 2\,\theta}{\frac{6 \times 5}{6}} \right)$$

$$= 7{\cdot}26\,(6\cos\theta - \cos 2\,\theta)$$

WEIGHT IN CONNECTING ROD.

The following are the exact formulæ:

$$F' + f'' = F = 7{\cdot}26\,(6\cos\theta - \cos 2\,\theta)$$

The weight being distributed uniformly between the centres of cross head and crank pins, $f'' = F' = \dfrac{F}{2}$, and the square of the radius of gyration $= z^2 = \frac{1}{3}\rho^2$. Then equations (b), (c), (d), (e) and (f), give

$$F'' = \frac{f''\sin\theta\cos\beta}{\sin(\theta - \beta)} = \frac{\frac{1}{2}F}{1 - \frac{1}{6}\cos\theta}$$

$$f_1 = 2{\cdot}4\cos 2\,\theta,$$

$$F_1 = \frac{14{\cdot}5\cos 2\,\theta}{6 - \cos\theta},$$

$$f_2 = -\,14{\cdot}4\sin\theta,$$

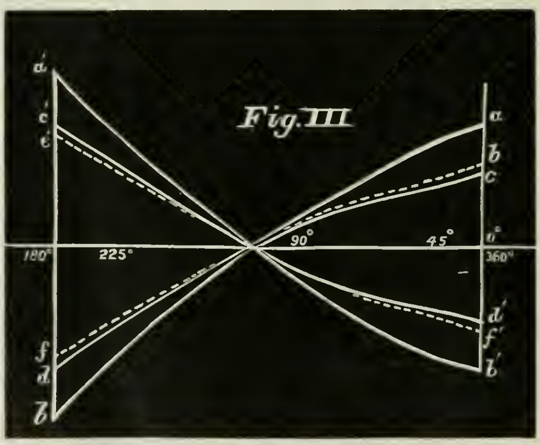
$$F_2 = \frac{86{\cdot}8 \cos\theta}{6 - \cos\theta}.$$

The following are numerical values of these expressions:

	0°	15°	30°	45°	60°	75°	90°	105°	120°	135°	150°	165°	180°
$F =$	36·3	35·5	34·0	30·8	25·4	17·5	7·2	− 5·	−18·1	−30·8	−41·4	−48·3	−51·
F'	18·1	17·7	17·	15·4	12·7	8·7	3·6	− 2·5	− 9·	−15·4	−20·7	−24·1	−25·5
F''	22·	21·	19·8	17 5	13·8	9·2	3·6	− 2·	− 8 3	−13·8	−18·1	−20·7	−21·9
f_1	2·4	2·1	1·2	0·	− 1·2	− 2·1	− 2·4	− 2·1	− 1·2	0·	1·2	2·1	2·4
F_1	2·9	2 5	1·5	0·	− 1·3	− 2·1	− 2·4	− 1·9	− 1·	0·	1·	1·8	2·1
f_2	0·	− 3 8	− 7·2	−10·2	−12 2	−14·	−14·4	−14·	−12·2	−10·2	− 7 2	− 3·8	0·
F_2	−17 4	−16·6	−15·7	−11·5	− 7·9	− 3·9	0	3·6	6·8	9 1	10 9	12·	12·4
$F + F_1 + F_2$	21·8	21·4	19·8	19·3	16·2	11·5	4·8	− 3·3	−12·3	−21·7	−29·5	−34·5	−36·5
$F' + F'' + F_1 + F_2$	25·6	24·6	22·6	21·4	17·1	12·	4·8	− 2·8	−11·5	−20·1	−27·9	−32 8	−33·
$F + f_1$	38·7	37·5	35 2	30·7	24·	15·4	4·8	− 7·	−19·3	−30·7	−40 5	−46·5	−49·

GRAPHICAL REPRESENTATION.

In *Fig. III*, the curves of acceleration for each case are drawn.

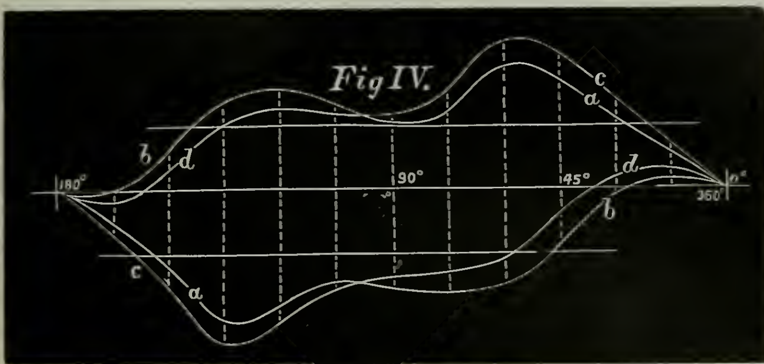


The lines $a\ b$ and $a'\ b'$ are the acceleration curves when the weight is concentrated in the cross-head, the ordinates being the values of F in the preceding table.

The curves $c\ d$ and $c'\ d'$ are obtained by using the approximate formulæ (1), (2), etc., the weight being placed in the connecting

rod. The broken lines $e\,f$ and $e'\,f'$ are obtained by using the exact formulæ.

As this is an extreme case, we infer that the difference in the results given by the exact and approximate formulæ, will always be comparatively small; and as the value F_1 is always small, it follows that for all practical cases a sufficient approximation is reached by considering the values F and F_2 only.



In *Fig. IV*, the curves of tangential effort are drawn for each of the cases just considered. The indicator diagrams used are those in *Fig. I*.

For weight (300 pounds) in cross-head, we have—

Forward stroke $\dfrac{\Delta E}{\int p\,d\,s} = \cdot 258$

Backward stroke $\dfrac{\Delta E}{\int p\,d\,s} = \cdot 311$

Weight in connecting rod:

Forward stroke $\dfrac{\Delta E}{\int p\,d\,s} = \cdot 342$

Backward stroke $\dfrac{\Delta E}{\int p\,d\,s} = \cdot 351$

BALANCING OF ENGINES.

The object of balancing an engine is to give to the engine-frame the least possible shake.

In this investigation, the counter-weight is supposed to be con centrated at a point 180° from the crank and at a distance from

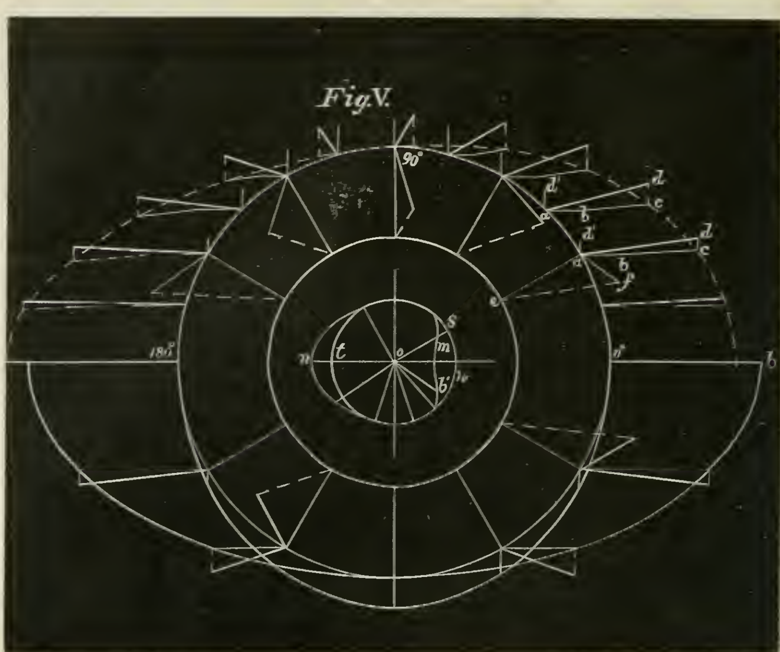


Fig. V.

the shaft equal to the length of crank. In *Fig. V*, the resultant of the forces due to inertia and to the centrifugal force of counter-weight is found for every 15° in the circumference. The forces are treated as though they were centred at the crank pin and the resultant only transmitted to the main shaft.

The force due to the inertia of the cross head and piston is transmitted along the connecting rod, and is known in direction and intensity, being $F \sec \beta$.

The vertical force f_2 and the direction of F, due to the lateral motion of the connecting rod, are known.

The longitudinal acceleration of the connecting rod is produced by two forces, one at each end of the rod.

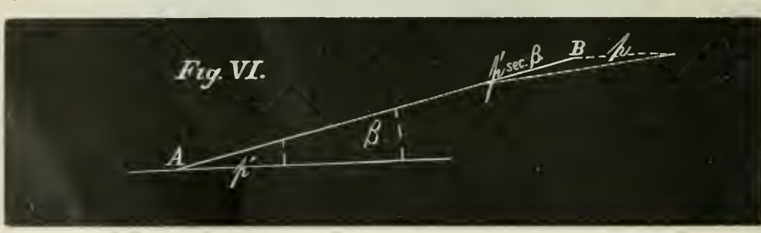


Fig. VI.

Let the forces p and p', *Fig. VI*, parallel to the piston rod, act at the ends of the line $A\,B$, the end A moving between guides. The stress along the rod due to p' will be $p' \sec \beta$. The resultant of these forces, p and $p' \sec \beta$, acts in a direction which is so nearly parallel to the guides that it is treated as being exactly parallel.

The centrifugal force acts radially outward from the centre of the crank circle.

In *Fig V*, the construction for determining the proper counter-weight for the Porter-Allen engine, before described, is made, the weight of the parts being 310 pounds. Take the point 30° from the centre line, and make $a\,b = F + f_1 =$ the force accelerating the rod longitudinally. $b\,c = F \sec \beta$, laid off parallel to the connecting rod, $c\,d = a\,d' = f_2$, then will $a\,d =$ the resultant of these forces.

The centrifugal force of the counter-weight being represented by $a\,e$, which is constant throughout the revolution, lay off $e\,f$ equal and parallel to $a\,d$, and the resultant $a\,f = o\,f'$ will represent the force producing the shake carried to the shaft. The proper length $a\,e$ may be determined by trial. The pull on the shaft for every point in a revolution is the radial distance to any point in the line $b'\,m\,n$.

When the obliquity of the rod is neglected, the lateral force being considered however, F is laid off horizontally. This construction gives a circle, $r\,s\,t$. It is seen that the counter-weight $a\,e$ is the same as before. This is the method used by Professor Robinson in his paper on "Balancing,"* in which he states that the horizontal forces are limited by ellipses, as shown in the lower part of *Fig. V*.

The difference in the two solutions is very apparent on examining my construction above, and his below the centre line.

The line $a\,e$ equals the centrifugal force of the counter-weight. To determine the weight we have—

$$\frac{W}{g} \times \frac{\omega^2 R}{\pi r^2} = \text{value of } a\,e \text{ in lbs.}$$

Fig. VII shows how nearly balanced the 300 pounds placed entirely in the cross-head or in the connecting rod can be. The construction on the right is for the weight in the cross-head; there

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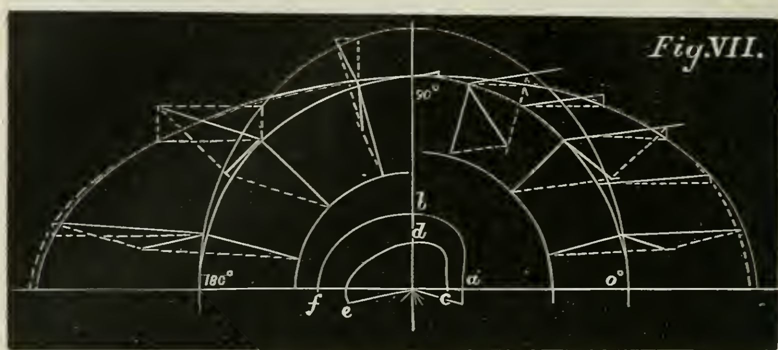
* Read before the American Society of Mechanical Engineers, 1881.

is no lateral force, the only force being $F \sec \beta$. The line $a\ b$ when the obliquity of the cross-head is considered, is found to approach more nearly to a circle for this case.



The construction on the left is for the weight in the rod. The line $d\ e$, when the obliquity of the rod is neglected, is the nearest approach to a circle in this case. The area of this curve is much smaller than the curve $a\ b$, hence it follows that the shake is less when the weight is concentrated in the connecting rod than when it is in the cross-head. This conclusion was reached by Professor Robinson, in the paper before referred to. But that writer states that the absorption of power at the beginning of the stroke is the same in either case; that this is not so is seen by referring to *Fig. III*, the difference in the accelerating forces in this case at $0° = 11$ pounds per square inch, while at the end of the stroke the difference is eighteen pounds per square inch.

ELECTROLYTIC ALUMINIUM.—L. Senet has devised a new process for obtaining aluminium, as well as copper, silver, etc., by electrolysis. He exposes a saturated solution of sulphate of alumina, separated from a solution of chloride of sodium by a porous vessel, to a current of six or seven volts and four ampères. The double chloride of aluminium and sodium is decomposed, and the aluminium is deposited upon the negative electrode.—*Cosmos, Aug. 10, 1885.*

INFLUENCE OF TEMPERATURE UPON THE TORSION-COUPLE OF WIRES.—The experiments of M. Baille show that temperature exercises an appreciable influence upon the value of the torsion-couple of wires. The couple diminishes very rapidly when the temperature increases; the variations amount to about one per cent. per degree Centigrade for aluminium and silver. Care is therefore necessary to maintain a constant temperature when making measurements with apparatus in which the effects to be measured are equilibrated by the torsion of a wire.—*L'Électricien, Oct. 10, 1885.*

INORGANIC FOODS.

By N. A. Randolph, M. D.

[*A Lecture delivered before the* Franklin Institute, *December 7, 1885.*]

In considering the different food-stuffs, we must regard water as of prime importance. In the average adult this body constitutes from fifty-nine per cent. to sixty-five per cent. of the entire weight. Older observers have given this proportion somewhat higher; thus Bernard, following Chaussard, gave the average proportion of water in the human economy as ninety per cent. This, however, was far too high, the error lying in the desiccation of the cadavers investigated, which were in this case subjected to destructive distillation. Of the entire water of the body, we find fifty-five per cent. in the muscles and only three per cent. in the cerebro-spinal system and nerve trunks. We further find the amount correlated with the age of the individual; thus, in mice, there is found in the embryo eighty-seven per cent. of water; in the new-born, eighty-two per cent., and at eight days old, seventy-six per cent.; in the adult mouse, seventy per cent. In advanced age, in all mammalia, the tissues are again rich in water as in early youth. As the result of bad nourishment also, the organism becomes richer in water; thus, a carnivore (*e. g.*, a dog) fed on bread will lose relatively little in weight, but will lose much urea, which substance, it need scarcely be said, is a result of the disintegration of the nitrogenous tissues of the body, such as muscle. On feeding him with meat he at once loses weight and passes by various channels far more water than is ingested, although he is in reality gaining in flesh. A bread or potato diet favors the accummulation of water in the tissues of the human economy, also with the resultant false appearance of health and misleading plumpness of the individual. On returning, however, to a normal dietary containing the proper proportion of proteid material, there is a similar decrease in weight, and the water leaves the body literally in streams. We must regard water as an essential condition for the manifestation of all vital phenomena. It is a common carrier of pabulum to each minute part, and at the same time a scavenger for the removal of the waste products. Most chemical reactions

and the action of ferments require water, as do also the molecular movements of nerve-conduction and muscular contraction.

The percentage of water in organs cannot be greatly altered without corresponding disturbances in health. In certain diseases, as cholera, there is a diminution in the percentage of the water contained in the tissues of from five to six per cent. As a result of this, however, the blood becomes thick and slow in its movement, urine is no longer excreted, and further removal means the death of the individual, or, in the lower forms of life, a suspension of all the vital activities until such time as the water removed shall be restored. Thus, the common wheel-animalcules may be completely dried and kept, free from moisture, as an impalpable powder; but on the addition of water to this powder the animals in question immediately resume all vital activities, and if subjected to microscopic examination cannot be distinguished from other living and moving infusoria of the same genus.

In the adult human body water is constantly lost by urine, fæces, skin and lungs, chiefly, however, through the former channel. The amount of water daily eliminated varies from two to three litres. It is renewed and its normal proportion maintained by various drinks, the fluid portion of foods, and by the oxidation of carbohydrates. By this last method alone from three-fourths of a pint to one pint of water is daily formed in the average adult body. No decomposition of water occurs in the economy.

In starvation the percentage of water is not decreased in spite of constant losses. This is due in part to production of water by the oxidation of carbohydrates, just mentioned, and to the fact that as the albumens of the body are destroyed in starvation the water which was combined with them becomes free. On this account combined hunger and thirst is more easily borne than thirst alone. Excess of water ingested only temporarily increases the water percentage of the various organs, the loss by the kidneys, etc., being almost immediate; but before its excretion this excess of water must circulate from cell to cell throughout the entire body, and in so doing it not inconsiderably increases the activity of the tissues. Thus, in experiments upon himself, Genth found that in his usual daily life he excreted from forty to forty-five grammes of urea. When, however, he drank from two to four litres of fluid in excess of his habitual amount, the amount of urea excreted was

from forty-six to fifty-five grammes; that is, an increase of from fifteen to twenty-two per cent.

In children, with whom both tissue-activity and tissue-destruction is very great, there is again a great demand for water, and an interesting clinical fact, first emphasized, I believe, by the late Dr. Meigs, of this city, is that in the great majority of cases in which children cry without apparent cause, the origin of their distress is lack of the water needed to wash away the products of tissue-change.

From a hygienic standpoint it is of the greatest importance that the water drunk shall be pure, and the following brief rules by Fischer, perhaps the best authority upon this matter, will be found of service:

The water must be clear, colorless and odorless. The extremes of temperature through which it should exist at different times of the year are narrow, viz., from 6° to 12° C. (40·8° to 50° F.). It must not contain more than the most minimal amount of organic matter (·04 of one per cent.), absolutely none of the organisms of decay, bacteria, etc. It must contain no ammonia or nitrous acid, and less than one-tenth of one per cent. of nitrates, sulphates and chlorides. It must not contain more than ·04 per cent. of magnesia, and, of course, no poisonous metals.

Certain solid inorganic elements of food are absolutely essential to the well-being of the organism, for in their absence the tissues cannot be properly built up, nor can the processes in either the solids or the fluids of the body go on. But for the constant renewal of these inorganic or ashy constituents of the body, not only would the characteristic activity of gastric and pancreatic juice and bile sooner or later be rendered impossible but some of the inorganic materials already existing in the tissues would be seized upon by the various acids—uric, sulphuric, etc.—which are constantly developed in the retrograde metamorphosis of tissue and be excreted as salts, with a resultant loss of the normal degree of alkalinity of the juices of the body and finally death. The presence of mineral constituents appears absolutely essential to the integrity of proteid matter, and their withdrawal entails a loss of most of its distinguishing characteristics. We find no coagulable proteid without its quota of inorganic salts, and these salts appear to be in a state of chemical union with the albuminoid. Thus in the

lowest organisms, as the amœba, we find an appreciable quantity of alkaline salts, notably phosphates. Casein also is a proteid body remarkable for the tenacity with which it holds incorporated with it a large amount of phosphate of lime. Now, inasmuch as these inorganic constituents of the body are constantly passing from the economy in the excretions, they must as a consequence be renewed. The full importance of these substances was first appreciated by Liebig, whose attention was directed to the subject by his studies in agricultural chemistry. Since the overthrow of his views as to the rapidity of tissue waste and repair, the subject of the inorganic food-stuffs has not received the attention which its importance merits. The question of the amount of this form of food which is essential to the organism is as yet unsettled. Certain it is, however, that in earlier life relatively greater quantities of the salts are needed, and that their absence from the food at this period produces results much more marked and immediate than would the same conditions in adult life.

In starvation there is a continual elimination of the inorganic salts, which is explained by the fact that these salts are constantly set free in the destruction of the circulating albumens with which they were previously in comparatively firm chemical combination. When, on the other hand, there is attempted the so-called salt starvation, viz., the administration of proteids, fats, carbohydrates and water, all in ample quantity, but from which all existing salts have been removed, the excretions are marked by a nearly complete absence of the inorganic salts. The cause of this apparent anomaly lies in the fact that the salts which were combined with the albumens of the tissues and circulating fluids are by the normal disintegration of these albumens set free, but instead of being eliminated they enter into immediate combination with the newly-introduced saltless albumens of the circulation. This can endure, however, but for a relatively short period; for in such recombination there is an inevitable failure to unite of a portion of the salts, which are thereupon excreted, resulting in such a diminution of the ashy constituents of the body as ultimately to induce death.

Pigeons thus subjected to starvation by the withdrawal of all inorganic foods die in from thirteen to twenty-nine days, although abundance of the other food constituents may be given them. In twenty-six to thirty-six days dogs similarly treated are reduced to

such a miserable condition that a continuance of the observation would mean almost immediate death. The characteristic symptoms of this species of starvation are muscular weakness and trembling, gradual blunting of the senses, with occasionally heightened reflex activity, and, finally, impaired digestion and death. No well-marked changes are found in the bones of adult animals, which have died under this regimen; but with young animals the case is different. Young pigeons of the same age have been fed with wheat from which the major portion of the inorganic materials was removed by maceration; to one series of these pigeons this wheat was given with distilled water; to another series was given the same wheat with brook-water, in which bits of mortar were allowed to stand. All the animals grew for a time, but those of the first series all died, exhibiting the symptoms of rachitis, while those of the second series remained to all appearances in good health. An examination of the bones showed that those of the pigeons receiving no inorganic salts contained full ten per cent. less of solid matters than did those of the normally fed. Apart from the absence of lime salts in the food, diseases of the bone may supervene in young animals in which protracted diarrhœa or other digestive disturbances have prevented the proper absorption of inorganic foods.

Perhaps the most striking illustration of the necessity of this class of food stuffs, and also of the disturbances resulting from a very slight diminution in the amount of inorganic constituents present in the economy, may be found in the recent experiments of Ringer. In these experiments minnows were placed in distilled water which was properly aërated. They died in a few hours. Minnows of the same age were similarly placed in brook-water, and remained alive without any food for many days. An examination of the distilled water in which the minnows had so speedily died, revealed the presence of minute traces only of inorganic bodies, which had evidently dialyzed out from the body of the fish into the surrounding medium—a loss so slight as scarcely to be estimated, and yet sufficient to entail the destruction of the individual.

Examining now the inorganic elements of food somewhat more closely in detail, we find them to consist of the salts of the alkalies, salts of the alkaline earths, and of iron, silica, and fluorine in

various combinations. There are also found in the excreta several bodies which have been erroneously regarded as excreted inorganic food-stuffs, which are really products of tissue-activity. As instances in point may be noted, the carbonates and sulphates of the urine, which proceed almost exclusively from the breakdown of vegetable acids and of proteid tissues respectively. The compounds of the several alkalies with chlorine and with phosphoric and carbonic acids are differently distributed, as was first noted by Liebig. Thus in the firmer tissues, as is notably the case in muscle, there is found a preponderance of salts of potassium, while in the circulating fluids and juices of the body, the sodium salts are found in greater abundance. The salts of the alkalies are chiefly removed from the body in the urine, being scarcely to be found in the fæces of carnivora, and when found in the fæces of men and animals, on a mixed diet, they arise from the imperfect absorption of foods which contain them. In diarrhœa, and in the semi-fluid excreta of many herbivoræ, they are present in notable quantity from the same cause. Under normal conditions the alkaline reaction of the saliva is due to the presence of salts of sodium ; but in inflammatory conditions of the mouth-cavity the dominant salts secreted are those of potassium. This fact would seem correlated with the observation of Mannassein, that in fever the amount of the salts in the muscles is diminished, as a result of which there is excreted in urine three to four times as much potassium in fever as in health. A similar action is also observed in starvation.

The nature of food, and to a large extent, the nature of its inorganic constituents, imparts characteristic reactions to the urine ; thus vegetable foods as a rule contain a notable excess of the alkaline salts of potassium, and we accordingly find in the urine of herbivoræ a decidedly alkaline reaction. When, however, an herbivorous animal is placed upon animal food, as is the case with a sucking calf, or what is the same thing, a starving cow which is consuming its own tissue, the urine assumes an acid reaction, due to the presence of acid sodium phosphate. The rationale of the secretion of acid fluids is but imperfectly understood. Ralfe has pointed out that under the influence of a weak electric current a decomposition occurs between neutral sodium phosphate and sodium bicarbonate, both of which exist in the blood, with the production of the acid sodium phosphate and normal sodium bicarbonate. This view is in some measure confirmed by the

repeatedly confirmed observation that an increased acidity of the urine occurs after the administration of the bicarbonates of potassium, sodium and ammonium.

The importance to the economy of the carbonates of the alkalies, and therefore the importance of fresh vegetable food from which they are most readily elaborated, must not be underestimated. To them is largely due the alkalinity of the circulating fluids of the body, an alkalinity whose disturbance is inevitably fatal. Reduction of the alkalinity of the circulating fluids is, however, difficult to attain; amounts of dilute acid have been introduced into the stomach, and without marked disturbance, which, if absorbed and excreted without change, would have been more than sufficient to render acid all the solids and fluids of the economy. When, however, the floods capable of yielding carbonates as the vegetable acids and the alkalies, are withheld, there is a different result, the elimination of the acids constantly forming in the functional activity of the tissues is retarded, and when excreted they carry with them the salts of the body, with the ultimate production of the symptoms of scurvy. When, therefore, the alkaline constituents of the economy are for a long time withheld, we note diminished alkalinity of the circulating fluids, with dissolution of the red corpuscles, ecchymoses on the mucous surfaces of the heart and mediastinum and fatty degeneration of the heart and general muscular system, and also of the glandular organs.

The production of a free acid, viz., as hydrochloric acid in gastric juice, fro n an alkaline fluid, the blood, presents a problem of some interest. It has been explained by the double decomposition occurring between acid sodium carbonate and sodium chloride, with the resultant production of normal sodium carbonate and hydrochloric acid. Some observers would substitute calcium chloride for the sodium chloride in the reaction just given; but in any case the principle is the same. That the hydrochloric acid once formed should leave the blood for the stomach is not incomprehensible, for the diffusive power of this acid ranks among the highest. Such reactions as these are valuable accessions to knowledge; and are very necessary steps in our approximations to ultimate truth; but why such reaction should occur in the stomach and not elsewhere is as yet unknown.

Of the uses of potassium chloride but little is known. Sodium

chloride, however, has been more closely studied. The infant at the breast receives daily on an average during its first year about twelve grains (.79 of a gramme) of salt. The adult undoubtedly takes proportionately more, and this excess can be regarded as of value chiefly as a condiment; that is, as a stimulant to appetite and digestion, which acts by pleasing the sense of taste. Salt when introduced into the economy, either by the stomach or directly into the veins, begins to appear in the urine within an hour thereafter. The maximum of excretion is reached in the third hour, and in eight hours it is all eliminated. A curious mutual relation exists between the salts of potassium and those of sodium; an excess of sodium chloride in the food produces an increased renal elimination of the salts of potassium. The converse also holds good, viz., an excess of potassium salts in foods induces a rapid excretion of sodium chloride to such an extent that intense salt hunger is experienced. This is not felt by men and animals living upon a food relatively poor in potassium. To men fed, as are to a large degree the poorer classes in many countries, upon products of wheat, rye, potatoes, and the leguminosæ, all of which are relatively rich in potassium, salt becomes more than a condiment; it becomes an indispensable food, for it withdraws the potassium salts which otherwise—it would seem chiefly by their action upon the nervous system—poison the economy. Common salt in such proportions as the healthy taste demands is undoubtedly a valuable stimulant to the nutritive processes. All agriculturists agree that the herbivorous animals of the farm thrive better upon the addition of salt to their food. It is further well known that the withdrawal of common salt from the food of domestic animals induces many symptoms of impaired nutrition.

We have already discussed the absolute necessity for lime-salts in young animals, but the extent of this need is surprising. The experiments of Soxhlet, Lehman, and Weiske coincide in showing that for the calf at ages of from two weeks to five months there is needed from ten to fifteen grammes of calcium daily. A large proportion of the lime salts used in the human body are obtained from drinking water.

Iron, popularly regarded as a drug, is undoubtedly a food, for concurrently the iron in the tissues and fluids of the body is being separated from its inorganic combinations and eliminated while the

fresh increments are being taken up from the food. Its avenue of elimination is almost exclusively by the fæces, though traces are to be found in the urine. Contrary to popular belief, the major portion of the iron of the human body is found, not in the blood, but in the muscles, even after their contained blood has been removed. It must, therefore, be borne in mind that the amount of iron found in the excreted matter is not a direct indication of the extent of the disintegration of hæmoglobin. The precise amount of iron which is needed daily by the average adult is not fully established, but it is evidently quite small. Perhaps the best approximation to the amount required may be obtained from the analysis of the normal mother's milk. On this basis an infant during the first year uses daily three and one-third milligrammes of iron, or in other terms, a trifle less than twenty grains a year. In the healthy adult, in whom tissue waste is not so pronounced, and with whom also there are no claims for the process of growth, it is probable this amount will be fully sufficient if presented in the appropriate form for its proper assimilation.

Silicic acid is found in very small quantities in bones, hair and blood. It is supplied by many vegetable foods. Calcium fluoride is found in teeth, and to a slight extent in bone.

Fortunately for us, these inorganic foods, whose withdrawal, as we have seen, exercises such deleterious influences on the economy, are, as a rule, present in great quantity in the actual foods in a mixed diet. In certain methods of preparing foods, however, their proportion is much diminished; thus, in the boiling of meats and vegetables, a large quantity of these important food-stuffs is extracted. Indeed, one of the chief dietetical advantages of salads and uncooked vegetables in general is that these elements have not been removed.

There is a very rational and economical method employed in French family cookery, which it would be well to employ in this country. This consists in the use of a large pot, whose contents are kept constantly at a gentle heat, and into which is poured all the water in which meat and vegetables have been boiled. After some simmering down, this extract, with some addition of flavoring, forms not only a good and appetizing soup, but retains as a food what otherwise would have been lost, viz., the inorganic food-stuffs whose value we have just considered.

REPORT OF THE COMMITTEE ON SCIENCE AND THE ARTS ON ROBERT H. RAMSEY'S CAR TRANSFER APPARATUS.

HALL OF THE FRANKLIN INSTITUTE,
Philadelphia, June, 1886.

The Sub-Committee of the Committee on Science and the Arts, constituted by the FRANKLIN INSTITUTE of the State of Pennsylvania, to whom was referred, for examination,

ROBERT H. RAMSEY'S CAR TRANSFER APPARATUS,

Respectfully report: That they have examined this invention, and the specifications of the letters-patent thereon and numerous testimonials of its operation and merits, and have also examined into the extent of its field of applicability and usefulness.

The invention is the subject of three (3) letters-patent of the United States, granted to ROBERT H. RAMSEY, the inventor, formerly of Cobourg, in the County of Northumberland, in the Province of Ontario and Dominion of Canada, and now of the City of Philadelphia and State of Pennsylvania, and are respectfully numbered and dated as follows:

No. 178,079, May 30, 1876, surrendered and re-issued as re-issue. No. 8,259, dated May 28, 1878, and No. 204,087, dated May 21, 1878.

Copies of the specifications and drawings of these patents are appended to this report.

The invention has for its object the expeditious and easy changing, under car bodies, of the trucks adapted to run upon railways of one gauge for trucks adapted to run upon railways of a different gauge, thus avoiding the delay and expense of breaking bulk or removing freight or passengers from the cars fitting one gauge of road to those fitting roads of another gauge, and of course avoiding the risk of accidents and mistakes incident to changing of cars by passengers and transfer of freight from one car to another.

The means employed to affect the change of trucks, consists of a depressed portion of the main tracks of the roads of both gauges laid parallel one within the other, and at the sides of this depressed

portion of the tracks are other tracks of the grade of the main line extending somewhat beyond both ends of the incline entering the depressed portion of the track, and upon these side tracks are fitted wheeled trucks, which, being placed at the sides of a car before entering the incline part of the track and having beams, or bars, placed across them under the body of the car, carry the car body at the grade of the road supported upon the side truck and tracks, whilst the truck of the car descending the incline is disengaged and remains in the depressed portion of the track, and as the car progresses, the king-bolts engage trucks having wheels of the other gauge previously placed on the depressed track, and these trucks rising on the other incline, receive the weight of the car body and permit the withdrawing of the beams, thus disengaging the side trucks and leaving the car ready to run upon the road of another gauge.

As above described, there appears a necessity for the application of motive-power to effect the transfer, which, in fact, was the case as the invention was originally made, and your committee have so described it here (as it is shown in the earlier letters-patent) in order that the full scope of the invention, as afterwards improved and perfected, may be more readily understood and appreciated.

As shown in the later letters-patent, and in practical use, the side tracks are laid with a grade sufficient to furnish propelling force adequate to carry the car over the depressed portion of the track, and lift the second set of trucks upon the incline to the road of differing gauge. In order to do this, side tracks, provided with proper switches, connect the two roads and permit the entrance of all cars at the upper end of the inclined side tracks.

By this arrangement of inclined side tracks, and having depressed parts of the main line and the inclined approach and exit graded to conform thereto, the change of trucks is easily and promptly effected without using any other motive-power than that provided by the grade, a feature of additional importance when it is considered that the requirements for transfer from one gauge to another are most frequent where branch roads, with limited motive-power, are thus connected with main lines at points where the business would not warrant the maintenance of shifting engines.

In the improved form of the apparatus, the side tracks are made

to diverge at the ends beyond the inclines, so that in entering, by being placed at the sides of passenger cars or other wide cars having steps at the ends, the side trucks pass under the edges of the car body between the steps, and support the car body without requiring the use of cross beams, and at the opposite end are similarly disengaged after being relieved of the weight of the car body.

In practice, in order to remove and introduce trucks to the depressed portion of the track, a transfer table is provided, by means of which trucks can be passed out laterally under the side tracks to sidings at the grade of the depressed tracks. The plane of motion of the transfer table, and its connected storage trucks, being level and the trucks being without load upon them, they are easily handled by the force of men usually required at such stations.

The invention has been extensively introduced and is in successful operation, saving time, labor and expense.

The field for its useful application is extensive, in numbers there being no less than 345 places in the United States, on June 1, 1885, where change of gauge leaves no other alternative than change of wheels or the breaking of bulk; and 144 additional miles of narrow-gauge road were built up to May 30, 1886.

It is demonstrated to be well adapted to the service in the hands of men usually employed in railway service, and for the great value and saving of time, trouble, labor and expense, your committee deem it entitled to the most serious consideration as a proper claimant of the high award asked for it, to wit: the Elliot Cresson Medal.

In submitting this report to the committee, the sub-committee feel it their duty to present the evidences which are adduced as to the excellence of the invention and its successful work, and also the proofs showing the broad extent of the field in which it is beneficially useful, rather than to state their conclusions. Entertaining these views, the sub-committee append to this report a statement showing the number of breaks of gauge requiring transfer, the locations where this invention is in use and testimonials showing the views of those having charge of railways using it.

Your committee are well aware that extensive changes of gauge have recently been made, having in view the uniformity of gauge to the 4 feet 9 inches standard, which might at first sight tend to show a contraction of the demand for this invention, but when it is considered that each branch of the roads of differing gauge demands a

Direction of Cars while being transferred from Broad- to Narrow-Gauge Trucks. ☞

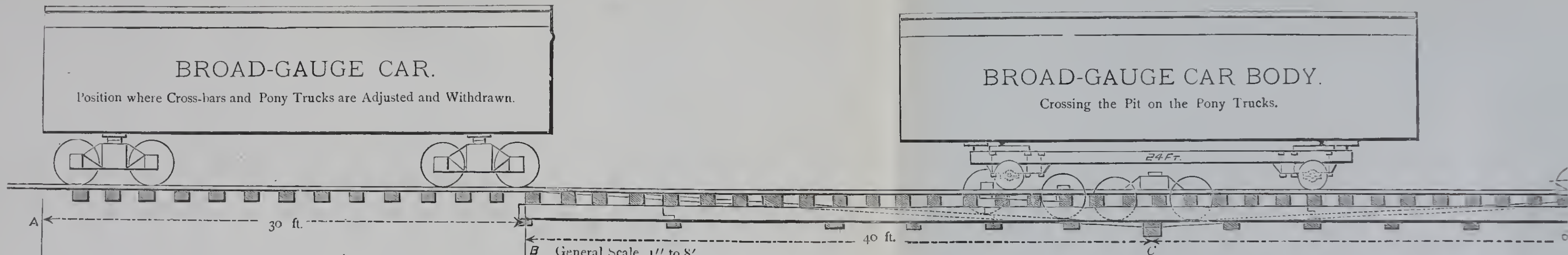


FIGURE I.

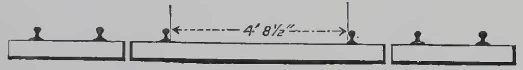


FIGURE 2.
Cross Section from A to B.

RAMSEY'S CAR TRANSFER APP

THIS FORM OF CONSTRUCTION IS ADAPTED TO LIGHT NARROW-GAUGE FEEDERS. THE CAR BODIES ARE HAULE

Direction of Cars while being transferred from Narrow- to Broad-Gauge Trucks.

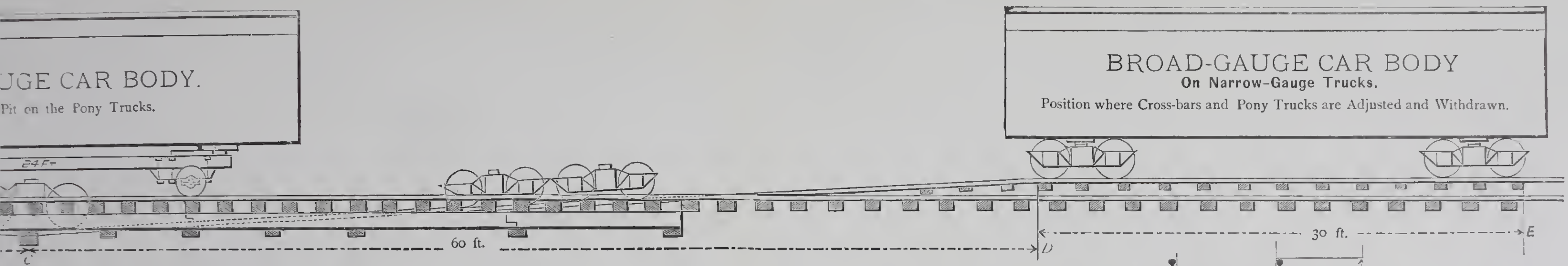


FIGURE I.

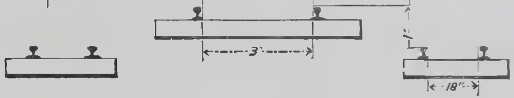


FIGURE 3.
Cross Section from D to E.

AR TRANSFER APPARATUS.

GAUGE FEEDERS. THE CAR BODIES ARE HAULED OVER THE DEPRESSION OR PIT WITH A SWITCH ROPE.

transfer instead of the one main line, and the development of narrow-gauge roads in sections where no other road can be afforded, this invention cannot fail to appear as of utmost importance in connecting vast sections of the country with the commercial centres without breaking bulk, thus bringing the producers and consumers closer to each other and greatly promoting the thrift of the country.

Your committee therefore submit this report and the evidences upon which this recommendation is based, with confident belief that the invention fairly deserves upon its merits the high award that has been solicited for it, and that the proofs submitted, fully sustain such conclusion.

Respectfully submitted,

S. LLOYD WIEGAND, *Chm.*,
LUTHER L. CHENEY,
JOHN L. GILL, JR.,
EDWARD LONGSTRETH,
ALEX. E. OUTERBRIDGE, JR.,
RUFUS HILL.

Approved July 7, 1886.

H. R. HEYL, *Chairman.*

APPENDIX.

List of Railways in Operation in the United States that cannot Interchange Freight in Bulk with Standard-Gauge Roads without changing Trucks; also, a list of Narrow-Gauge Railways now under Construction and to be Constructed; Compiled and Tabulated to date of July 1, 1886, by R. H. Ramsey, 207 East Chelten Avenue, Germantown, Philadelphia, Pa.

To the Committee on Science and the Arts of the FRANKLIN INSTITUTE:

GENTLEMEN:—In connection with my application for an examination and report upon Ramsey's Car Transfer Apparatus, I beg to present the following tabulated statement, with accompanying papers compiled to date of July 1, 1886, as showing the large and increasing field for its operations.

	No. of Railways.	Mileage.	No. of Breaks of Gauge.
Narrow-Gauge Railways in the U. S., . .	211	12,829	355
Broad-Gauge (5′ and over) R'w'ys in the U. S.,	14	187	15
Total number of breaks of gauge in the U. S.,			370

	In 1884.	In 1885.	To June 30, 1886.
Total mileage of railway track laid in the U. S., ...	3,997	3,200	1,755
Mileage of narrow-gauge railway track laid in the U. S., ...	552	534	258
Percentage of narrow-gauge track laid, about,	14%	17%	14·7%

	Miles Track laid in 1886 to June 30th.	Miles now under Construction.	Miles to be Constructed.
Narrow-gauge railways in the U. S., . . .	258	437	1,553

Total railway mileage in the U. S., December 31, 1884, .	125,379
Mileage railway construction in the U. S. for 1885, . . .	3,200
Mileage railway construction in the U. S. for 1886 to July 1st,	1,755
Total railway mileage in the U. S. to July 1, 1886, . .	130,334
Total narrow-gauge railway mileage, ...	12,829
Less 713 miles Mexican National Railway in Mexico, . .	713
Total narrow-gauge railway mileage in the U. S., . .	12,116

being 9·2 per cent. of the railway system of the United States.

Reference to papers marked A, will show the extent of the narrow-gauge system now in operation in the United States, the name of each railway with its mileage, and the number of its junction points with railways of different gauge. I am aware of the fact that within a short time several of these narrow-gauge railways that parallel standard roads will be changed to standard gauge, but after such change amounting altogether to about 2,000 miles, there will still remain over 10,000 miles of narrow-gauge feeders.

Reference to papers marked B, will show those railways of a wider gauge than the standard. It has been the general impression that the reduction of the gauge to standard from five feet in the Southern States would obviate the necessity for car transfer: the fact is, however, that, previous to the recent change of gauge there were but thirty-six points where a break of gauge occurred between five feet and standard, and at six of these a break

still exists between three feet and standard. While thirty points were destroyed by the change, twelve new ones were created, leaving but eighteen breaks of gauge destroyed by the change of about 12,000 miles of five-feet gauge railway.

Reference to papers marked C, will show that the narrow-gauge system so far from having "seen its best days," is constantly resorted to in the development of mountainous and sparsely populated districts; California taking the lead in extensions and new roads with twelve, Georgia, Florida and Texas with seven each, etc.

There are also a large number of narrow-gauge railways owned and operated by private parties, for lumbering, mining, etc., which not being open for public business are not mentioned by the railway authorities and are found only in the circulars and pamphlets of locomotive builders, etc., which have not been included in these papers.

Very respectfully yours,

R. H. Ramsey.

Germantown, Philadelphia, May, 1886.

[A.]

NARROW-GAUGE RAILWAYS IN OPERATION IN THE UNITED STATES, WITH THEIR MILEAGE AND NUMBER OF BREAKS OF GAUGE.

	Mileage.	*Breaks of Gauge.*
Addison and North Pennsylvania,	47	2
Anniston and Atlantic,	45	3
Arizona and New Mexico,	71	1
Arkansas Midland,	58	2
Atlantic and Danville,	55	2
Augusta, Gibson and Sandersville,	51	2
Austin and Northwestern,	60	2
Americus, Preston and Lumpkin,	38	2
Altoona Coal and Iron Company's,	9	1
Atchison, Topeka and Santa Fé, from Deming to Silver City,	47	1
Apopka and Atlantic,	5	1
Batesville and Brinkley,	56	2
Bath and Hammondsport,	9	1
Bedford and Bloomfield,	41	2
Bellaire, Zanesville and Cincinnati,	112	4
Boston, Revere Beach and Lynn,	9	1
Boston, Winthrop and Shore, "N. G. Div.,"	7	1
Bradford, Bordell and Kinzua,	41	3
Bradford, Eldred and Cuba,	54	3

	Mileage.	Breaks of Gauge.
Boston and Lowell, "N. G. Div." From Bethlehem Junction to Profile, etc.,	14	1
Buffalo, New York and Philadelphia, "N. G. Div.," Olean to Kinzua and Eldred,	70	4
Burlington and Northwestern, and Burlington and Western,	105	4
Bodie and Benton,	37	..
Brighthope,	32	1
Buckley and Douglass,	9	..
Bear Lake and Manistee River,	5	..
Bowden Springs,	4	1
Battle Mountain and Lewis,	10	..
Black Hills,	15	..
Bridgeton and Saco River (2′ gauge),	16	1
Cadillac and Northeastern,	13	1
Carson and Colorado,	301	1
Carson and Tahoe,	10	1
Catskill Mountain and Cairo,	14	1
Central Vermont, "N. G. Div." From South Londonderry to Whitehall,	36	1
Chargin Falls and Southern,	5	1
Chataugay,	34	1
Cincinnati and Southeastern,	17	1
Cincinnati, Georgetown and Portsmouth,	42	2
Cincinnati, Lebanon and Northern,	59	5
Clarksburg, Weston and Glenville,	40	1
Cleveland and Canton,	157	7
Columbia and Puget Sound,	45	1
Columbus and Rome,	51	1
Colusa,	10	1
Coudersport and Port Alleghany,	17	1
Crown Point Iron Company's,	13	1
Cedar River,	24	..
Crescent Springs,	12	1
Chowan and Caskie (3′ 6″ gauge),	8	..
Cold Spring and Hamburg (3′ 2″ gauge),	3	1
Crooked Creek, "Lehigh to Judd,"	9	1
California and Nevada,	17	1
Cincinnati and Eastern,	133	4
Columbus and Maysville,	17	1
Danville and New River,	75	1
Danville, Mocksville and Southwestern,	28	1
Dayton and Ironton,	118	7
Dayton and Toledo,	96	6
Deerfield River,	11	1
De Land and St. John's River,	3	1
Denver and Rio Grande,	1,317	3

	Mileage.	*Breaks of Gauge.*
Denver and Rio Grande and Western,	368	2
Denver, Utah and Pacific,	44	1
Des Moines, Osceola and Southern,	111	5
Deadwood and Woodville,	10	..
East and West of Alabama,	110	3
East Broad Top,	36	1
Eastern and Western Air Line,	56	4
East Tennessee and Western North Carolina,	34	1
Eureka and Palisade,	90	1
Evergreen,	4	1
Eureka Iron Company's,	2	..
Florida Southern,	338	8
Flint and Père Marquette "N. G. Div."		
Mount Pleasant to Coleman,	15	1
Fort Madison and Northwestern,	41	3
Fulton County,	61	5
Franklin and Megantic (2′ gauge),	15	..
Galveston, Sabine and St. Louis,	28	1
Georgia "N. G. Div."		
Gainsville, Jefferson and Southern,	65	2
Gainsville and Dahlonega,	5	1
Georgia Pacific (Mississippi Division),	52	1
Georgia Marble Company's,	3	..
Grafton Centre,	3	1
Green Cove and Midland,	10	1
Greenlick,	4	1
Grafton and Greenbriar,	24	1
Hartwell,	10	..
Havana, Rantoul and Eastern,	76	6
Herkimer, Newport and Poland (3′ 6″ gauge),	17	1
Hot Springs (3′ 6″ gauge),	25	1
Houston, East and West Texas,	232	4
Hancock and Calumet,	18	..
Hecla and Torch Lake (4′ 1″ gauge),	6	..
Hobart and Manistee River,	10	..
Henrico Branch of Richmond and Alleghany,	11	1
Indiana, Illinois Southern and Bloomfield,	89	5
Indiana, Alabama and Texas,	30	1
Jacksonville and Atlantic,	17	..
Jacksonville, Tampa and Key West, "N. G. Div."		
Jacksonville to St. Augustine,	36	2
Kaaterskill,	8	..
Kansas and Gulf Short Line,	89	2
Kentucky and South Atlantic,	23	1
Knoxville and New River,	20	1
Keystone Coal Company's,	6	1

	Mileage.	Breaks of Gauge.
Lackawanna and Pittsburgh "N. G. Div."		
Olean to Angelica,	44	4
Lac La Belle and Calumet,	8	..
Louisville and Nashville, "N. G. Div."		
From Louisville to Prospect,	11	1
Longdale Iron Company,	7	1
Maine Central (Bucksport Branch),	18	1
Marietta and North Georgia,	88	1
Maryland Central,	45	1
Mexican National, 713 miles in Mexico, balance 175 miles in Texas,	888	5
Mineral Range,	15	2
Minneapolis, Lindale and Minnetonka,	26	4
Missouri Pacific "N. G. Div."		
Jefferson to McKenney,	155	3
Sedalia to Warsaw,	42	1
Mobile and Northwestern,	30	2
Montgomery Southern,	20	1
Montrose,	28	1
Martha's Vineyard,	9	..
Mendocino,	4	..
Moline and Southeastern,	8	2
Muskrat Lake and Clam River,	8	..
Marshall, Paris and Northwestern,	17	1
Memphis Branch,	5	1
Monson (2′ gauge),	8	1
Nantucket,	11	..
Nashville, Chattanooga and St. Louis, "N. G. Div."		
Dickson to Etna,	44	1
Duck River Branch,	48	2
Natchez, Jackson and Columbus (3′ 6″ gauge),	100	2
Natchez, Red River and Texas,	28	..
Nevada Central,	93	1
Nevada and California,	30	1
Nevada County Narrow-Gauge,	23	1
Norfolk and Virginia Beach,	17	1
Norfolk and Ocean View,	8	1
North Pacific Coast,	87	1
Napa City and Lakeport,	15	..
New Castle Railroad and Mining Co. (3′ 6″ gauge),	6	1
Nantasket Beach (purchased by "Old Colony R. R.),	7	1
Nevada, branch from "You Bet" Station, Nevada Co. N. G.,	12	..
Olympia and Chihalis Valley,	16	1
Oregonian,	149	2
Pacific Coast,	64	..
Painesville and Youngstown,	61	5

	Mileage.	*Breaks of Gauge.*
Paw Paw, Toledo and South Haven,	20	2
Peach Bottom,	20	2
Pennsylvania Coal Company's (4′ 3″ gauge),	63	1
Pittsburg and Western "N. G. Div." Callery Junction to Mt. Jewett, etc.,	151	5
Port Huron and Northwestern,	218	4
Potomac, Fredericksburg and Piedmont,	38	2
Pine Bluff and Swans Lake,	26	1
Pennsboro' and Harrisville Ritchie Company,	9	1
Page's (3′ 2″ gauge),	3	1
Paint Creek,	5	..
Richmond and Danville "N. G. Div."		
State University Branch,	10	1
Suwannee to Lawrenceville,	10	1
Toccoa to Elberton (Elberton Air Line),	51	1
Roswell Railroad,	10	1
Chester and Lenoir,	109	4
Cheraw and Chester,	29	..
Milton and Sutherland,	7	1
Virginia Midland N. G. Branch, Franklin Junction to Rocky Mountain,	37	1
Rio Grande, Texas (3′ 6″ gauge),	22	..
Rockwood and Tennessee River,	6	1
Rome and Carrollton,	22	1
Ruby Hill,	7	..
St. Clairsville (3′ 1″ gauge),	7	1
St. Joe and Des Loge,	13	1
St. Joseph's Valley,	10	1
St. Louis, Arkansas and Texas,	735	13
St. Louis, Crève Cœur and St. Charles,	16	2
Saginaw, Tuscola and Huron,	49	2
San Pete Valley,	35	1
San Joaquin and Sierra Nevada,	41	1
Saratoga, Mt. McGregor and Lake George,	11	1
Ship Island, Ripley and Kentucky,	26	1
Sonoma Valley,	21	1
South Florida,	149	2
South Pacific Coast,	100	3
Stony Clove and Catskill Mountain,	14	1
Stockton and Amador,	30	1
St. John and Halifax,	40	..
Salt Lake and Western,	57	1
Suffolk Lumber Company's,	35	..
St. Louis and Cairo,	160	4
St. Augustine and Palatka,	30	2
Soddy Coal Company's,	4	..
Sandy River (2′ gauge),	18	1

	Mileage.	Breaks of Gauge.
Talladega and Coosa Valley,	13	1
Tennessee and Sequatchi Valley,	12	1
Texas Western,	53	2
Tionesta Valley,	32	1
Toledo, Cincinnati and St. Louis,	450	24
Tonawanda Valley and Cuba,	59	2
Tuskegee,	5	1
Union Pacific, "N. G. Divs."		
Denver and South Park,	321	1
Denver to Central City,	40	1
Forks Creek to Graymont,	31	..
Boulder to Pennsylvania Gulch,	14	1
Utah and Northern,	465	4
Kansas Central Branch,	166	3
Utah and Nevada,	37	1
Wabash, St. Louis and Pacific "N. G. Div."		
Des Moines to Fonda,	115	6
Walden's Ridge,	23	1
Warren to Farnsworth Valley,	15	1
Waynesburg and Washington,	29	1
Worcester and Shrewsbury,	3	1
West Branch and Moorestown,	10	..
York and Peachbottom,	40	1
Total,	12,829	355

[B.]

BROAD-GAUGE RAILWAYS IN OPERATION IN THE UNITED STATES, WITH THEIR MILEAGE AND NUMBER OF BREAKS OF GAUGE.*

	Mileage.	Breaks of Gauge.
†Bouge (from Bouge Station W. C. and A. R. R.), (5′ gauge),	8	1
†Cincinnati and Green River (5′ gauge),	13	1
†Cahaba Coal (Blocton, Alabama, to Woodstock) (5′ gauge),	10	1
†East Alabama (5′ gauge),	22	1
†Georgetown and Lands (5′ gauge),	37	1
†Louisville and Wadley (5′ gauge),	10	1
†Mobile and Spring Hill (5′ 2″ gauge),	8	1
†Pensacola and Perdido (5′ gauge),	10	1
†Sylvania (5′ gauge),	14	1
†Sandersville and Tennille (5′ gauge),	3	1

* Owing to the recency of the change of gauge from five feet to standard in the South, this list (while correct as far as it goes) is but partial. Complete information at this time is not at hand. [R.]

† These railways are not included in the list of those having changed their gauge.—Additional references, Poor's *Manual and Official Guide.* [R.]

	Mileage.	Breaks of Gauge.
Silver Lake (6′ gauge),	7	2
Sterling Mountain (6′ gauge),	8	1
*Tennessee Coal and Iron (5′ gauge),	21	1
*Wrightsville and Tennille (5′ gauge),	16	1
Total,	187	15

[C.]

MILEAGE OF NARROW-GAUGE RAILWAYS IN THE UNITED STATES, CONSTRUCTED IN 1886 UP TO JUNE 30TH, NOW UNDER CONSTRUCTION, AND TO BE CONSTRUCTED.

	Miles.		
	Construction in 1886 to June 30.	Now under Construction.	To be Constructed.
Americus, Preston and Lumpkin,	9	26	..
Addison and North Pennsylvania,	..	..	10
Austin and Northwestern,	..	..	28
Apopka and Atlantic,	..	7	..
Augusta, Edgefield and Newberry,	..	..	85
Atlanta and Hawkinsville,	..	..	125
Atlantic and Danville,	..	..	120
Anniston and Atlantic,	..	..	25
Augusta, Gibson and Sandersville,	..	20	..
Arkansas Midland,	7	..	..
Augusta and White Plains,	..	30	..
Bodie and Benton,	..	..	9
Batesville and Brinkley,	8	..	11
Bartlett Mountain (Maine),	..	..	8
Bartlett Land and Lumber Company (New Hampshire),	..	..	8
Bowden Springs,	1	4	..
Cincinnati, Georgetown and Portsmouth,	4	..	..
Chataugay,	..	16	..
Colusa,	..	..	39
Chatham Beach,	..	8	..
Denver, Aspen and Grand River,	..	..	105
Denver, Utah and Pacific,	..	..	30
Denver Railroad and Land Company,	7	9	..
Deadwood,	..	..	..
East and West Railroad of Alabama,	..	..	35
Florida Southern,	87	..	40
Fort Mason, Seneca and St. Johns,	..	..	25
Forbestown to Moore's Station,	..	..	22
Galveston, Sabine and St. Louis.	..	..	110

* These railways are not included in the list of those having changed their gauge.—Additional references, Poor's *Manual and Official Guide.* [R.]

	Miles.		
	Construction in 1886 to June 30.	Now under Construction.	To be Constructed.
Houston, East and West Texas,	..	..	100
Jacksonville, St. Augustine and Halifax River,	..	..	36
Kingwood and Tunnelton,*	..	11	..
Kansas and Gulf Short Line,	..	..	25
Kansas City, Independence and Park,	..	..	10
Longdale Iron Company,	..	12	..
Lima and Rush Junction,	..	..	9
Montgomery Southern,	..	..	30
Marietta and North Georgia,	18	45	..
Marshall, Paris and Northwestern,	5	30	..
Minneapolis, Lindale and Minnetonka,	..	10	..
Nevada and California,	..	..	31
North Pacific Coast,	8	..	..
Northwestern, of California,	..	..	51
Napa City and Lakeport,	..	15	..
Natchez, Red River and Texas,	9	..	..
Niagara Falls and Whirlpool,	..	..	4
North Conway and Mt. Kearsarge,	..	..	26
Ormsby and Mt. Jewett,	..	..	9
Pine Bluffs and Swans Lake,	..	7	33
Pittsburg and Western,	6	..	3
Portland and Willamette Valley,	..	..	40
Pacific Coast,	..	40	..
Rome and Carrollton,	..	43	..
Rockport and Limerick,	..	..	3
Ravenswood, Spencer and Glenville,	..	..	45
Rapid City and Southwestern,	..	..	30
San Joaquin and Sierra Nevada,	..	..	12
Sierra Valley and Mohawk,	..	..	35
Sonoma Valley,	..	..	36
St. Johns and Halifax River,	40	40	..
Saginaw, Tuscola and Huron,	..	..	20
South Pacific Coast,	9	27	..
Shreveport and Houston,	1	..	..
St. Augustine and Palatka,	30	..	..
St. Augustine and Pablo Beach,	..	..	30
Tavares, Apopka and Gulf,	..	25	40
Tionesta Valley,	4	..	..
Texas Western,	..	..	50
Talladega and Coosa Valley,	5	12	..
Utah and Nevada,	..	..	10
Totals,	258	437	1,553

RECENT PROGRESS IN CHEMISTRY.

By H. Carrington Bolton, Ph.D.,
Professor of Chemistry, Trinity College, Hartford.

[*An Address read before the New York Academy of Sciences, March 15, 1886.*]

To many intelligent and cultivated persons not specifically instructed in chemistry, this word recalls confused memories of colored liquids, glistening crystals, dazzling flames, suffocating fumes, intolerable odors, startling explosions, and a chaos of mystifying experiments, the interest in which is proportional to the danger supposed to attend their exhibition. Further reminiscences are of many singular objects in wood, metal, glass and earthenware, of flasks and funnels, of retorts and condensers, furnaces and crucibles, together with bottles innumerable, filled with solids, liquids and gases, the whole paraphernalia connected by glass tubes of eccentric curves, and displayed in inextricable confusion and meaningless array. Behind this chaos arise vague memories of one discoursing learnedly in a polysyllabic jargon, and attempting to explain the unusual phenomena by the aid of abstruse hypotheses, but utterly failing to remove the sensations of awe and of mystery bordering on the supernatural which overwhelm the hearer—impressions that have clung to chemistry ever since its entanglement with the superstitions of alchemy, astrology, and the "black art."

Persons who undertake to gain through chemical literature a knowledge of what chemists are doing in and for the world, encounter a discouraging nomenclature which repels them by its apparent intricacy and its polysyllabic character. Their opinion of the terminology of an exact science is not enhanced when they learn that "black lead" contains no lead, "copperas" contains no copper, "mosaic gold" no gold, and "german silver" no silver; that "carbolic acid" is not an acid, "oil of vitriol" is not an oil, that olive oil is a "salt," but "rock oil" is neither an oil nor a salt; that some sugars and some kinds of wax are alcohols; that "cream of tartar" has nothing in common with

cream, "milk of lime" with milk, "butter of antimony" with butter, "sugar of lead" with sugar, nor "liver of sulphur" with the animal organ from which it was named.

Readers of chemical writings sometimes fail to appreciate the advantages of styling borax "di-meta-borate of sodium," or of calling common alcohol "methyl-carbinol," and they ignore the euphony in such words as pentamethyldiamidothiodiphenylamin-diiodomethylate (a substance begotten and baptized by Dr. Albert Maasen).

Those whose chemical education consisted in attendance on a course of lectures illustrated by experiments performed in their presence, interspersed with occasional recitations from a prosaic text-book which taxed the memory in true Chinese fashion, may be pardoned for retaining very hazy impressions of the true character of the science. On the other hand, many thinking and reading persons recognize the magnitude of the scope and operations of chemistry, and have some appreciation of its benefits to mankind.

The fields of chemistry explored by zealous investigators are prodigious in extent and diversity; in its various sections, analytical, agricultural, pharmaceutical, physiological, and technological, it yields fruit of infinite value to the human race, and co-operating with other sciences, produces results which promote civilization in the highest degree. So rapidly are new methods of cultivation applied to these fields, so numerous and active are the workmen engaged in tilling them, that the harvest is too abundant for mental storage, and those who survey the operations at a distance are quite unable to apprehend the products. This inability to follow the advances made by chemical science is felt not alone by those whose imperfect and non-technical training has illy fitted them for the task; even the specialist stands aghast at the prospect, and abandoning attempts to apprehend the progress made in all departments, confines his reading and research to a limited number.

The twelve principal chemical societies of the world have an aggregate membership of over 8,000;[1] nearly all of these members are actively contributing to the advancement of chemical science, publishing their results for the most part in periodicals especially devoted to the subject. Excluding transactions of societies, and

journals of physics and pharmacy. these chemical periodicals issue annually about 20,000 pages. Bearing these statistics in mind, are we not justified in feeling appalled at the idea of presenting within the compass of an evening's address a review of recent progress in chemistry? Any attempt to do more than glance at a few salient points is obviously out of the question. "Recent" time will of necessity be a somewhat variable quantity, its limits being determined by expediency. We shall also endeavor to bear in mind the fact that we address an audience not exclusively composed of professional chemists.

Much interest is commonly attached to announcements of new forms of matter—an interest out of proportion, perhaps, to the real value of the discoveries. During the last nine years chemists have not failed to sustain this interest, for they have proclaimed no less than thirty-one new elementary bodies. The ambition of these chemists, however, has been greater than their accuracy, for of these thirty-one bantlings but five or six have survived the scrutiny of the doctors, two or three are now in precarious health, and the remainder have been buried or cremated without ceremonies. Of the youthful survivors comparatively little is known; their character is being severely tested, and their future destiny and utility are yet uncertain. The extreme rarity of the minerals in which the new elements have been detected, the excessively small percentages of the new ingredients, the extraordinary difficulties attending their separation from known substances, combine to render the investigations laborious, protracted and costly. From 2,400 kilogrammes of zinc blende, Lecoq de Boisbaudran, the discoverer of gallium, extracted sixty-two grammes of the precious metal; compared with this element, therefore, gold is both abundant and cheap. Ytterbium, scandium, samarium, thulium, and the rest, will long remain mere chemical curiosities known to but few; probably the most sanguine will not claim for them a future place among substances of economic value.[2]

But of far greater importance than the elements themselves is the marvelious delicacy of the means used in detecting and isolating them. When Bunsen and Kirchhof presented to scientists the instrument which combines the penetration of a telescope with the power of a microscope magnified an hundred-fold, they were enabled to disclose Nature's most hidden secrets. The new elements have

been traced to their hiding-places, their differences established, and their subsequent purity demonstrated, chiefly by their emission and absorption spectra. Three years ago, William Crookes, who had already discovered thallium by the aid of the spectroscope, announced a novel and remarkable extension of the power of this instrument. Crookes[3] found that many substances, when struck by the molecular discharge from the negative pole in a highly rarefied atmosphere, emit phosphorescent light of varied intensity. Having observed under these conditions a bright citron-colored band or line, he pursued the substance producing it, and, after a laborious search, found that it belonged to yttrium. Subsequent studies showed this modification of spectrum analysis to exceed in delicacy all known tests for the rarer earths; yttrium can be detected when present in $\frac{1}{1\,000,000}$ part. Within a twelvemonth, Crookes has made known the application of radiant matter spectroscopy to samarium; the delicacy of this test surpasses that for yttrium, and the anomalous behavior of the mixed earths yields phenomena "without precedent."[4]

About the same date as the later communication by Crookes, Lecoq de Boisbaudran[5] published a method of obtaining what he terms "reversion spectra," which is practically the same in effect as that of Crookes. The French savant finds indications of two new elements in certain brilliant lines, but Crookes distinctly warns us that "inferences drawn from spectrum analysis *per se* are liable to grave doubt," and "chemistry after all must be the court of final appeal." Crookes' reflections on the sufficiency of spectrum observations as criteria of the elementary character of bodies are justified by the experience of many, notably of Sorby, whose pseudo jargonium is well remembered. This difficulty arises especially with absorption spectra, and neglect of the warning given by Sorby has led several chemists into fruitless researches.

When Dalton, the Manchester schoolmaster, added to the atomic theory of the Greeks the laws of definite and of multiple proportions, he transformed an "interesting intellectual plaything" into an exact scientific theory capable of experimental demonstration. The importance of ascertaining the atomic weights of the elements with the utmost accuracy has stimulated chemists to apply to the problem their best endeavors; and, as the methods of analysis become more refined, the determinations are again and

again repeated, every ascertainable and imaginable source of error being carefully eliminated. Beside the experimental repetitions, the figures obtained by various observers have recently been submitted to careful re-calculations by Clarke,[6] in this country, and soon after by Lothar Meyer and Seubert,[7] in Germany. Their labors give chemists the latest and most reliable constants.

The prevailing, though partly unacknowledged, adherence to Prout's hypothesis, leading chemists to prefer whole numbers (or at least even fractions) for the atomic weights, is liable to result in confusion and perplexity. Stas demonstrated that the atomic weight of oxygen is not quite sixteen times as great as that of hydrogen, but that when $H = 1$, $O = 15{\cdot}96$. The tendency to disregard this difference of $\frac{1}{400}$ is unfortunate, since important errors in calculations, based on organic analyses, might result therefrom. Lothar Meyer and Seubert show that in the analysis of compounds of carbon and hydrogen, the error introduced by making $O = 16$ is greater than the errors of observation, and in the analysis of a body belonging to a homologous series doubts might arise as to the identity of the body under examination.[8] Of course, the formula of a body is not determined by analytical data alone; still, this liability to errors marks forcibly the desirability of greater uniformity in the standard of values for the atomic weights.

Contrasting strongly with belief in the absolute character of the weights of atoms is the suggestion of Boutlerow and others, that the law of definite proportions is subject to variations. In 1880, Schützenberger observed a curious anomaly in analyzing some hydrocarbons. He found that the sum of the carbon and hydrogen was 101 for 100 parts of material, the result under other conditions being normal. Boutlerow called attention to this, and expressed the opinion that the chemical value of a constant weight (or, rather, mass) of an element may vary, and that the so-called atomic weight of an element may be simply the carrier of a certain amount of chemical energy which is variable within narrow limits. At a meeting of the Chemical Society of Paris, where Professor Wurtz presented a summary of the views of Boutlerow, an interesting discussion followed; this subsequently drew from Professor Josiah P. Cooke, of Harvard, a communication, in which he shows that he had expressed similar views more than twenty-five

years before. As early as 1855, he had questioned the absolute character of the law of definite proportions, and had suggested that the variability was occasioned by the very weak affinity between elements manifesting a fluctuating composition. These speculations are interesting to theorists, but do not seriously impugn the status of chemical philosophy.[9]

For many years chemists have dimly perceived the probable correlation of the properties of the elementary bodies and their atomic weights. Dumas pointed this out for certain marked groups, Newlands[10] emphasized it; but it remained for a Russian chemist, Mendelejeff,[11] to establish, in 1869, a law of great importance. Mendelejeff showed that if the elements are grouped in the order of their atomic weights, it will be found that nearly the same properties recur periodically throughout the entire series. This so-called "Periodic Law" is more concisely stated thus: The properties of the elements are periodic functions of their atomic weights. The accuracy of the deductions based on this law is strikingly shown by the fact that Mendelejeff, finding an unfilled blank in the periodic system, boldly announced the general and special properties of the element awaiting discovery. Six years later, Lecoq de Boisbaudran discovered gallium, an element which proved to have properties almost identical with those of the hypothetical *eka-aluminium* described by Mendelejeff. And, in 1879, the accuracy of Mendelejeff's prophecy was further confirmed by Nilson's discovery of scandium,[12] the counterpart of the hypothetical *ekabor*. *Eka-silicon*, though yet to be discovered, may almost be regarded as a known element, so fully have its properties been predicted[13]

The correlation between atomic weights and physical properties is being extended, and now embraces the fusibility, boiling points, general affinities, color, occurrence in nature, physiological functions, and many other factors.[14] Dr. Carnelley,[15] who has been active in developing this subject, at the Aberdeen meeting of the British Association, proposed a "reasonable explanation" of the periodic law.[16] He regards the elements as compounds of carbon and æther, analogous to the hydrocarbon radicals, and suggests that all known bodies are made up of three primary elements, carbon, hydrogen and æther—an assumption which cannot be disproved.

In recent years, the periodic system has exerted noteworthy influence on the classification of the elements and their compounds. It is of positive utility in determining unsettled questions concerning new and rare elements, and is destined to maintain a lasting hold on chemical philosophy.

The question whether the known elements are truly primary forms of matter has long occupied the thoughts of chemists, and the problem constantly acquires new features. The influence of high temperatures on the spectra of the metals has been a fruitful source of speculations. In 1878, the English astronomer and physicist, Lockyer,[17] announced the discovery of the resolution of the elements into one primary matter; but when Lockyer's paper was read before the Royal Society, his discovery proved to be little more than a hypothesis, and that not a new one, he having been virtually anticipated by Professor F. W. Clarke, of Washington.[18] However, Lockyer's hypothesis was based, in part, upon experimental evidence. After eliminating coincidences in the lines of the spectra of various metals, due to impurities, so large a number of identical lines remained that he advocated the assumption that these are produced by a primary matter common to the so-called elements. He pointed out that in the hottest stars, Sirius, for example, hydrogen only is present, and argued that at extremely high temperatures the so-called elements are broken up into hydrogen, the ultimate matter of the universe. Lockyer's announcement excited, temporarily, a lively interest, but his views are not regarded as supported by sufficient evidence.

More recently, the doctrine of "structure" has been borrowed from organic chemistry and applied to the elementary bodies. The relations existing between the elements is so similar in many respects to the relations between the hydrocarbons in a homologous series, that the elements have been regarded as compounds of carbon with an unknown primary form of matter. Experimental evidence is lacking, but the hypothesis takes a plausible form.

Dr. Carnelley, as elsewhere stated, suggests that elements are compounds of hydrogen, with the all-pervading æther of the physicist; but we venture to remark that attempts to explain the nature of elements by assuming them to be compounds of hydrogen with a substance whose very existence is itself assumed, is,

perhaps, an intellectual amusement, but not likely to advance the exact sciences.

During the past year an Austrian chemist has announced the decomposition of didymium by purely chemical means, and the discovery of praseodymium and neodymium as its constituent elements.[19] An English chemist claims to have evidence of the existence of an allotropic form of nitrogen.[20] Both these statements await confirmation.

The views of chemists concerning the nature of affinity and chemical action are undergoing modifications destined to wield an important influence on the science in the near future. The notion has prevailed, though not distinctly formulated, that the chemical attraction exerted between unlike atoms is a superior sort of cohesion, powerful and absolute; and this force was thought to operate between two elementary bodies directly, without the intervention of a third kind of matter. That this so-called affinity is radically affected by physical state, by heat, and by electricity has been admitted, but the conviction is growing in the minds of chemists that many circumstances influencing the union and separation of elements have been overlooked; they are beginning to believe that chemical action does not take place between *two* substances, and that the presence of a third body is important, if not, indeed, indispensable. Many years ago the word catalytic was coined to describe certain isolated phenomena little understood. These phenomena are familiar to chemists, and the number is increasing: the word catalytic is, however, in disfavor, and the term contact-actions is now current. The well-known influence of finely-divided and heated platinum in effecting the union of sulphur dioxide and oxygen, and the action of metallic silver in decomposing ozone without itself undergoing any change are examples. In these and similar changes one of the substances indispensable to the reaction remains unchanged, and its *rôle* cannot be expressed in equations.

Dulong and Thénard,[21] more than sixty years ago, showed that the temperature of ignition of a mixture of hydrogen and oxygen is lowered to a remarkable degree by the presence of solid bodies of varied nature. Within a few months, Menschutkin and Konowalow[22] have made a study of the influence of asbestos, glass and other bodies on the decomposition temperature of many organic compounds.

There is another class of reactions in which one body acts upon another only through the aid of a third, which maintains its identity at the close of the reaction, yet is known to be decomposed and recomposed successively throughout the operation. By heating a relatively small quantity of cobaltous chloride with bleaching powder, the latter is wholly decomposed, yielding calcium chloride, water and oxygen, yet at the close of the reaction the cobaltous oxide is found unaltered. It has been shown that it is successively decomposed and recomposed during the operation. In their investigation on "Simultaneous Oxidation and Reduction by Means of Hydrocyanic Acid," Profs. Michael and Palmer[23] consider it probable that many of the most important reactions of animal and vegetable life are due to the intercession of substances which undergo change during the reactions, and in the end return to their original form. They suggest also that some of these reactions seem to be dependent on substances capable of decomposing water into its elements, or into hydrogen and hydroxyl; and when the chemist can command a reagent possessing that property at a low temperature, their imitation in the laboratory may follow its discovery.

That chemically pure zinc is not soluble in dilute sulphuric acid has been known since Faraday's day; that sodium does not combine with perfectly dry chlorine, even if the metal be heated to its fusing point, was shown by Wanklyn[24] in 1869; more recently, Mr. Cowper has found that dry chlorine does not attack Dutch metal; six years ago, Mr. H. B. Dixon[25] demonstrated before the British Association that a well dried mixture of carbon monoxide and oxygen can be subjected to the electric spark without exploding. In March, 1885, Mr. H. B. Baker[26] communicated to the London Chemical Society results of his experiments on the influence of moisture in the combustion of carbon and of phosphorus in oxygen, his conclusions being that the combustion of dry charcoal in dry oxygen is incomplete and slower than in ordinary moist oxygen. In the discussion which followed Mr. Baker's paper, Dr. Armstrong pointed out the importance of these new facts in defining more accurately conceptions of chemical action, and suggested that chemical action is "reversed electrolysis." In his address as President of the Chemical Section of the British Association for the Advancement of Science (Sept. 10, 1885), Dr. Armstrong further discussed this subject, and stated that the idea

conveyed by the expression "reversed electrolysis" is found in the writings of Faraday, neglect of whose teachings retards the progress of chemistry.[27]

The influence of low and of high temperatures in retarding and facilitating chemical changes is fundamental, but some phenomena not generally known may be appropriately mentioned. Victor Meyer and Langer[28] have shown that whereas chlorine violently attacks platinum at low temperatures, it is without action upon the metal between 300° and 1,300°, and begins to act upon the platinum above the latter temperature, the action becoming violent at 1,600° to 1,700° C.

Liquefied ammonia at — 65° does not combine with sulphuric acid, but swims on its surface without mixing with it.[28A] Donny and Mareska[29] long ago showed that sodium retains its lustre in liquid chlorine at — 80°, and quite recently Professor Dewar demonstrated that liquid oxygen is without action on sodium, potassium, phosphorus, solid sulphuretted hydrogen, and solid hydriodic acid. He further experimented with other substances normally active, and found their affinity at very low temperatures destroyed.[30]

Attempts have been made to solve the problem of a general theory of chemical action by means of the data of electrolysis and of thermo-chemistry. The subject is further complicated by the phenomena of induction, of predisposing affinity, and of influence of mass. Lastly, but not least, the term affinity is itself used in a vague way, expressing different ideas at different times and by different authors, some writers doubting the expediency of employing the word at all, and favoring the more general expression chemical action. The true nature of chemical action has yet to be satisfactorily explained; only the most general conclusions are fairly deducible from the data in hand, namely: "that each chemical substance which forms a member of any changing system exerts a specific action on the course of the changes which that system undergoes."[31]

Chemists are beginning to realize that many phenomena regarded as simple in character are in reality quite complex. A single example must suffice. From Lavoisier's day until a few years ago the combustion of carbon monoxide in the air or in oxygen was regarded as a very simple phenomenon, satisfactorily explained by the equation:

$$2\,CO + O_2 = 2\,CO_2$$

in which two molecules of the gas unite directly with one of oxygen, producing two molecules of carbon dioxide. In 1880, however, Mr. H. B. Dixon[32] demonstrated that this reaction takes place only in the presence of aqueous vapor; this necessitates an entirely different explanation, as indicated in the following equations:

$$(1.)\ CO + H_2O = CO_2 + H_2$$
$$(2.)\ 2\,H_2 + O_2 = 2\,H_2O;$$

that is to say, the carbon monoxide decomposes the water forming carbon dioxide and setting hydrogen free, which latter gas unites with the free oxygen and thus reconstructs the water.

Within a twelvemonth, however, Traube[33] has shown that carbon monoxide does not decompose water in complete absence of air or oxygen, and hence Dixon's first equation does not represent a fact. Traube also finds that when moist carbon monoxide and oxygen are united by the electric spark, hydrogen peroxide is an invariable product, and he suggests the following explanation of the reaction:

$$(1.)\ CO + 2\,H_2O + O_2 = CO\,(OH)_2 + H_2O_2$$
$$(2.)\ CO + H_2O_2 = CO\,(OH)_2$$
$$(3.)\ 2CO\,(OH)_2 = 2CO_2 + 2H_2O.$$

These equations may be interpreted as follows: When the electric spark is passed through a mixture of carbon monoxide and oxygen in the presence of aqueous vapor, the first products are true carbonic acid and hydrogen peroxide; the latter at once oxidizes the carbon monoxide, forming a second molecule of carbonic acid; and, finally, the two molecules of carbonic acid are decomposed with the formation of carbon dioxide and water.

If Traube's views be sustained, it is evident that so simple a matter as the combustion of carbon monoxide has long been misunderstood, and disregard of the presence of moisture has led to erroneous conclusions.[34]

Chemists sometimes marvel at the blindness of the alchemists who, though familiar with many chemical processes in which gaseous bodies were evolved, yet disregarded these important factors, and left them for later generations to discover. What will

future generations think of us who fail to take into account accessory bodies indispensable to chemical reactions of the most familiar kind.[35]

The speed of chemical reactions is an important factor in chemical theory, the study of which has but recently begun. Wenzel[36] long ago held that the affinity of metals for a common solvent, such as nitric acid, was inversely as the time necessary to dissolve them, and he experimented with small cylinders, partly protected by wax. Gladstone and Tribe[37] have made attempts to ascertain the rate at which a metallic plate precipitates another metal from a solution, and they announced a definite law. Professor John W. Langley[38] has since shown that, while their experimental work was correct, their method was faulty, and the results fallacious; he thinks it probable that the true law of chemical action where one metal precipitates another should be thus stated. The time during which one atom replaces another in a compound molecule is constant, and the total rate of chemical action varies directly as the mass of the reacting body in solution.

In his address before the Chemical Section of the American Association for the Advancement of Science, at Philadelphia, Professor Langley[39] discussed the problems of chemical dynamics, and pointed out the rich store of promise in this neglected field. Physics deals with three quantities—space, mass and time. Chemistry has too long been content with studying the changes of matter in terms of space and mass only; that is to say, in units of atomic weight and atomic volume. The discovery of a time-rate for the attractions due to affinity is destined to throw new light on chemical science, and to render it capable of mathematical treatment.

A prodigious amount of work has been done in thermo-chemistry, and within a few years, the multitude of isolated observations have been collected, classified and made available. The importance of this undertaking will be more appreciated in the future than it has been in the immediate past.

In all cases of chemical change, energy in the form of heat is either developed or absorbed, and the amount is as definite in a given reaction as are the weights of the substances concerned; hence, measurement of the quantity of heat set free or absorbed in chemical reactions often enables the chemist to determine the true

nature of the change. For example, the exact condition of certain bodies in solution can only be conjectured from certain physical characters, few and ill-defined; but by thermic methods of investigation the bodies formed can be accurately ascertained. This is accomplished by reference to the law of maximum work. "In any reaction, those bodies, the formation of which gives rise to the greatest development of heat, are formed in preference to others." Thus the thermometer alone in skilful hands determines the *à priori* necessity or impossibility of a reaction.[40]

Berthelot,[41] in Paris, and Thomsen,[42] in Copenhagen, have pursued the subject of thermo-chemistry with indefatigable zeal, and their published results form monuments of exhaustive research. "By the labors chiefly of these two men, we now know the thermal values corresponding to many thousands of chemical reactions. We have learned that the energies of a reaction which can be brought about in two methods, either in the dry way or by solution, differ in the two cases; that salts in solution are in a partial state of decomposition; that the attraction of a polybasic acid radical is not the same for the successive portions of base added, and that the behavior of a monobasic acid in solution differs essentially from that of a dibasic or tribasic acid. We also know that the total energy involved in any reaction is largely influenced by the surrounding conditions of temperature, pressure and volume."[43]

The interesting border line between chemistry and physics is an increasing subject of research on the part of both the chemist and the physicist. The periodic press chronicles profound studies of the relations between chemical constitution and the phenomena of diffusion, of capillarity, of dialysis, of dissociation, and of the law of isomorphism. We read investigations on the value of the theory of atomicity, and on the nature of nascent action. Researches in the domain of electro-chemistry, especially in connection with the various forms of storage batteries, and in relation to the methods and results of electrolysis, are of such importance as to merit a whole address. The press also records numerous studies in actinometry, of the relations between chemical composition and fluorescence and phosphorescence, as well as of polychroism, and of the results of spectrum observations. Noteworthy are the special applications of optical methods to the determination of molecular structure, viz., the relations between chemical composition and (1)

the refractive power; (2), the power of rotating a ray of polarized light; and (3), the absorption spectra of both inorganic and organic bodies.

Bruhl has attempted to show that the relationship between refractive power and molecular structure is dependent on the valencies of atoms, and on the distribution of atomic interactions. Van 't Hoff has developed a hypothesis of a crystallographic character that cannot be discussed in the brief space at our command.[44]

The meeting of the French Academy of Sciences, held the day before Christmas, 1877, was rendered memorable by the announcement that oxygen gas had been liquefied by two independent experimenters. Previous to that date, hydrogen, oxygen, nitrogen, nitric oxide, marsh gas and carbon monoxide had resisted all attempts to liquefy them, whether in the hands of the skilful Faraday, the ingenious Natterer, or the learned Andrews. Physicists and chemists, while admitting the class of so-called permanent gases, had for many years looked forward to their eventual liquefaction, yet the final success came as a surprise. This success was the result of the enterprise and ingenuity of a French iron-master, M. Cailletet, and of a Genevan manufacturer of ice machines, Raoul Pictet, working independently. In each case the process consisted in simultaneously exposing the gases to a very high pressure and a very low temperature. Pictet[45] obtained the necessary pressure by generating the oxygen in a wrought-iron vessel strong enough to withstand an enormous strain, and the low temperature was secured by the rapid evaporation of liquid carbonic acid; Cailletet,[46] whose apparatus was marked by extreme simplicity, obtained the great pressure by means of an hydraulic press, and the low temperature by suddenly diminishing the pressure upon the compressed gases. Descriptions of apparatus without diagrams are seldom intelligible; in this place they are superfluous, for we deal with results rather than with methods. Being ignorant of the "critical point" for oxygen, both experimenters employed a much greater pressure than necessary.

Since the initial successes, the problem of liquefying the quondam permanent gases has been successfully attacked by several experimenters, especially by Wroblewski and Olzewski, whose names indicate their nationality.[47] By employing liquid ethylene

(which boils *in vacuo* as low as — 150° C. [— 238° F.]) as a means of cooling the gases under pressure, both oxygen and nitrogen, as well as atmospheric air have been liquefied at very moderate pressures.

Among the interesting results obtained are the following: At — 102° C. (—152° F.), chlorine forms orange-colored crystals; at — 115° C. (— 175° F.), hydrochloric acid is a solid; at — 118° C. (— 180° F.), arsenetted hydrogen forms white crystals; at — 129° C. (— 200° F.), ether solidifies; at — 130° C. (— 202° F.), absolute alcohol solidifies; at — 184° C. (— 299° F.), oxygen boils; at — 191·2° C. (— 312° F.), air boils; at — 205° C. (— 337° F.), air boils *in vacuo*. These extraordinary temperatures were measured by means of an hydrogen thermometer, and by a thermopile. The lowest temperature measured (to date) is — 225° C. (— 373° F.), which was reached by reducing the pressure of solid nitrogen to 4 *mm.* mercury [48] (Olzewski). Further noteworthy results are as follows: Nitrogen was obtained in "snow-like crystals of remarkable size;" the liquefaction of air has been so conducted as to obtain two distinct liquids separated by a perfectly visible meniscus (Wroblewski),[49] and, finally, when hydrogen was subjected to between 100 and 200 atmospheres pressure in small glass tubes surrounded by oxygen boiling *in vacuo*, it condensed to colorless drops.

These noteworthy results are triumphs of physics rather than of chemistry, but no review of chemical progress can afford to omit them; their bearing on the molecular theory of matter justifies the space given them. It seems probable, moreover, that every known substance on the face of the earth will be eventually obtained in solid form by the mere withdrawal of heat. At these low temperatures the chemical activity of bodies is greatly lessened or ceases, but additional observations must be made on this point before attempting generalizations.

Experiments of the character described demand great resources and are not devoid of danger; those conducting them will be rewarded by undying fame.

The progress of chemistry in its more material aspects is characterized by the improved and economic production of known substances, by the discovery and manufacture of entirely new ones, and by novel applications of both these classes as well as of waste

materials. The necessity of utmost condensation precludes enumeration of even a centesimal part of the processes and products, nor would the mere catalogue be profitable. Omitting for the present the prolific department of organic chemistry, brief mention may be made of improvements in the metallurgy of nickel[50] (now known to be malleable and ductile), of attempts to cheapen the production of aluminium,[51] of the revival of the barium dioxide process for manufacturing oxygen on a large scale,[52] of novelties in artistic keramics, of the industrial production and application of the rare metal vanadium, of the successful introduction of water gas as an illuminating agent, and of constant activity in the fascinating field of photography.

No chemical manufactures are more important than those grouped under the name: "Alkali Industry," which comprises the production of those adjuncts of civilization, carbonate of soda, caustic soda, bicarbonate of soda, and bleaching powder. Conducted by the methods originated by the ill-fated Nicolas Leblanc, they have, after a century's successful career, begun to give way to a youthful rival. The struggle to maintain the supremacy of Leblanc's process has been severe, the problem being a purely financial one. At first, the profits were made exclusively on the soda, then the decreasing profits, as well as the necessity of condensing the torrents of hydrochloric acid, led manufacturers to add to the production of alkali that of bleaching powder, and the latter then yielded the profits while the soda became a by-product. Sharp competition in England and France pushed prices below profitable production, and capitalists with millions involved found their chemical ingenuity severely taxed. Various economical methods of recovering waste by-products were adopted, and finally attention was turned to the "burnt ore" or "pyrites cinders" obtained in roasting pyrites for the sulphuric acid; this is now treated for copper, silver, and, to some extent, for gold. A Spanish company owning enormous deposits of pyrites on the Rio Tinto, plan to establish in France alkali works with the intention of deriving their profits solely from the residual oxide of iron and the copper.

Forty-eight years ago alkali manufacturers might have seen a cloud arising, no bigger than a man's hand, which gradually grew darker and heavier, and now threatens to overwhelm the Leblanc

process. Dyer and Hemming patented the so-called "ammonia process" for manufacturing soda, in 1838; Schlössing and Rolland attempted to carry it out practically in 1855, but it was not found profitable. The credit of overcoming the practical difficulties, and placing the process on an economical basis, belongs to Solvay, of Brussels, who began to manufacture so-called "ammonia soda," in 1866. Commencing with the modest yield of 179 tons in that year, he increased it in ten years to 11,580 tons, and in 1883, about forty per cent. of all the soda made on the continent was produced by the ammonia process. The success of the new process has completely killed the Leblanc method in Belgium, and has caused the closing of many works in England. A drawback to the new process is that no hydrochloric acid is produced, yet chloride of lime is always in demand; hence a high authority, Dr. Lunge, thinks that in the future the two processes will, of necessity, exist side by side.[53]

In modern chemical literature by far the greatest amount of space is occupied with researches and discoveries in organic chemistry. To the non-professional reader the peculiarly technical language, abounding in words of unusual length, is not only incomprehensible, but positively forbidding. A vocabulary which contains such terms as toluyldiphenyltriamidocarbinol acetate and methylorthomonohydroxybenzoate does not encourage the casual reader; and when he learns the first-named body is the dye-stuff commonly called magenta, and that the second is the innocent oil of wintergreen, surprise gives way to feelings of despair. When one is gleefully informed that a distinguished foreigner has discovered that orthobrombenzyl bromide treated with sodium yields anthracene, which, heated with nitric acid, yields anthraquinone, and that anthraquinonedisulphonic acid fused with potassium hydroxide furnishes dioxyanthraquinone, the lay hearer can hardly be expected to become enthusiastic over the announcement, and yet these operations conducted in the private laboratory of a man of genius have been of direct benefit to mankind, setting free thousands of acres for the production of breadstuffs, and establishing industries employing a multitude of workmen. In a word, these abstruse phrases describe the artificial production of alizarine, the valuable coloring matter of madder.

The polysyllabic nomenclature now prevailing expresses to the chemical mind the innate structural composition of the body

named; of late years the words are formed by joining syllables to an almost indefinite extent, and a distinguished chemist has recently urged the advantages of empiric names in place of the unwieldly system. Whether Dr. Odling's plea will produce a reaction in favor of empiric names remains to be seen.[54]

To enter into details concerning the recent progress of organic chemistry, and to make them intelligible to an audience not composed of well-read professional chemists, is an undertaking of doubtful success; we shall content ourselves chiefly with generalities.

That remarkable product of nature, petroleum, continues to occupy the studies of chemists at home and abroad. Newly invented methods of fractional distillation have disclosed previously unsuspected constituents and peculiarities. Lachowitz has found in the petroleum of Galicia several members of the aromatic series;[55] Mendelejeff has noticed abnormal relations between the specific gravity and boiling points of successive fractions in distilling American petroleum.[56] The various commercial products from crude petroleum, rhigolene, vaseline, paraffin, etc., continually find new and useful applications, their names being household words.

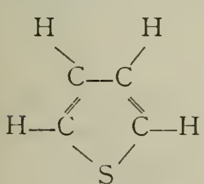
The industrial and scientific novelties in the important groups of oils and fats, alcohols, and acids, cannot be specified. After cane sugar, glucose is receiving the most attention; in the United States and Germany are sixty manufactories of the various grades of starch sugar, the annual home production alone being valued at $10,000,000. Glucose is extensively used as a substitute for cane sugar in the manufacture of table syrup, in brewing, in confectionery, in making artificial honey, and in adulterating cane sugar, as well as in many minor applications. Recent experiments by Dr. Duggan,[57] of Baltimore, show that glucose is in no way inferior to cane sugar in healthfulness. Much work has been done on sorghum by Dr. Peter Collier,[58] and the first complete examination of maple sugar has lately been made by Prof. Wiley,[59] of the Department of Agriculture. Lovers of the latter sweet will be pleased to learn that it can be made by adding to a mixture of glucose and cane sugar a patented extract of hickory bark, which imitates the desired flavor.

The great demand for high explosives as adjuncts to engineering, mining, and military operations occasions constant experimentation; besides the invention of mere empiric mixtures of

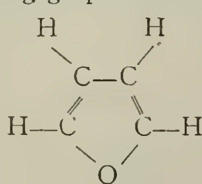
known substances, chiefly nitro-compounds, much work is done of a purely scientific nature, such as investigations on the chemical reactions and products of explosive mixtures, on the heat disengaged by their explosion, on the pressure of the gases produced, and on the duration of the explosive reaction. Thanks to the "Notes" of Prof. C. E. Munroe,[60] of the United States Naval Academy, chemists are informed of the freshest novelties in this department, rendering further mention superfluous.

The researches of chemists in the aromatic series outweigh in both number and importance those in all other sections. The once despised refuse coal-tar has created an entirely new chemistry, and, in its products and derivatives, is by far the most promising field for investigators. The compounds of the aromatic series have afforded some of the most notable successes in synthetical chemistry, as well as some of the most useful substances for dyeing, for hygienic and medicinal purposes. The oil obtained in the dry distillation of bones, a subject of classic investigations by Anderson,[61] of Glasgow, forty years ago, has recently acquired new interest; one of its constituents, pyridine (C_6H_5N), has been obtained in several ways, which show that it bears the same relation to certain acids derived from natural alkaloids, such as quinine, nicotine, etc., that benzene does to benzoic, and phthalic acids. These facts point to the possible artificial preparation of quinine at no distant day. This view of the constitution of the alkaloids is confirmed in many ways, notably by Ladenburg's discovery that piperidine, a base occurring in pepper, is hexahydrobenzene.[62]

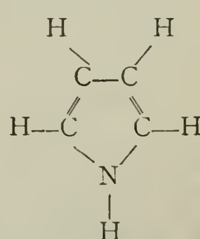
The discovery, by Victor Meyer,[63] of thiophene, a constituent of coal-tar benzene, having sulphur in its composition, is of more than passing interest. Meyer assigns to thiophene a structural formula, which shows its analogy to furfuran and to pyrrol. This is indicated in the following graphic formulæ:



Thiophene.



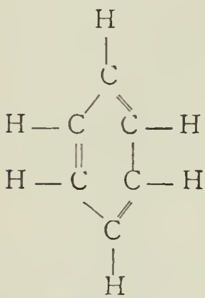
Furfuran.

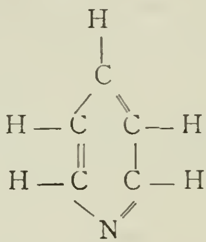


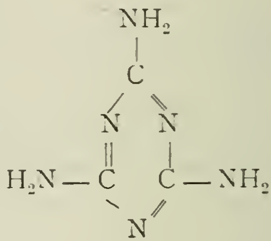
Pyrrol.

Professional chemists note with interest the important avenues of research opened up by the extension of the so-called ring structure of carbon compounds, and by the introduction of elements other than carbon into the closed chain of atoms. The demonstration by Kekulé, in 1865, that benzene contains a group of carbon atoms joined in such way as to form a regular hexagon, has wonderfully advanced our knowledge of the complex bodies in the aromatic series.

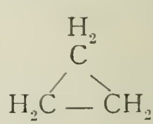
Numerous bodies are now known, whose structure is expressed by closed chains of three, four, five and six links. Dewar[64] was the first, we believe, to show that nitrogen can replace one of the carbon atoms of a six link chain in pyridine, and Hofmann[65] has shown that three atoms of nitrogen and three of carbon unite to form a closed chain in melamine:

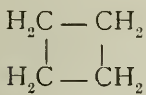
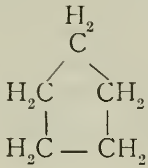
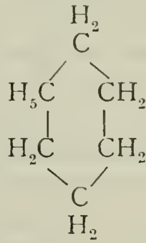

Benzene.


Pyridine.


Melamine.

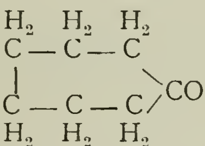
It has been a matter of surprise that no series intermediate between the open chains of the paraffin group and the closed ring of the benzene group have been made known. Quite recently, W. H. Perkin, Jr.,[66] in a remarkable memoir, has begun to fill up this wide gap, and he describes many bodies containing a three carbon atom ring, a four and a five carbon atom ring. The series of possible methylene-addition products is shown in the following schedule:

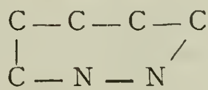
Methylene.	Di-methylene.	Tri-methylene.
$=CH_2$	CH_2 ‖ CH_2	

Tetra methylene.	Penta-methylene.	Hexa-methylene.
		

For details concerning derivatives of the above series, and the remarkable properties of some, we must refer to Perkin's published papers.

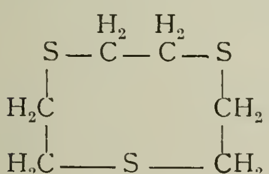
Professor Victor Meyer[67] has, within a few months, begun to investigate the possibility of obtaining closed chains containing a greater number of chains than six. He points out that, with the exception of the double rings, such as anthracene and acridine, only two bodies were known having seven links in a closed chain, viz.:

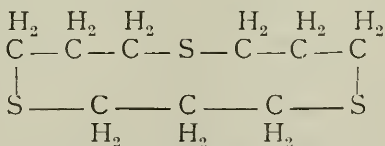




Suberone and Carbazostyril.

Professor Meyer, however, obtained bodies having nine and twelve links in closed chains, as indicated below:





These are substances of little stability, as, indeed, might be expected.

Professional chemists also acknowledge the marvellous success in unravelling the complications of isomerism, and the important aid afforded the study of isomeric bodies of the aromatic group by the doctrine of *orientation*. These rather technical details can

receive, however, but brief mention, though a whole series of lectures could be devoted to the fascinating topic. Leopold Gmelin, when writing his *Handbook of Chemistry*, in 1827, requested organic chemists to stop making discoveries, or else he could never finish. And during the sixty years which have elapsed, the activity in organic chemistry has been unceasing; yet the extraordinary number of facts now known is not so great as those which the prophetic eye sees disclosed by these recently revealed lines of investigation.

The crowning glory of chemistry is the power of producing in the laboratory, from inorganic matter, substances identical with those existing in the vegetable and animal kingdoms. Belief in the mysterious vital force operating in living beings received a rude shock at the hands of Wöhler, sixty years ago, and successive triumphs in synthesis have dispelled it entirely, so far as non-organized bodies are concerned: "to-day, we know that the same chemical laws rule animate and inanimate nature, and that any definite compound produced in the former can be prepared by synthesis as soon as its chemical constitution has been made out." Within a few years, chemists have announced the synthesis of many acids, essential oils, alkaloids, glucosides, dye-stuffs, and other bodies naturally occurring in the organic world, and so rapidly do these announcements succeed one another that expectation has displaced surprise. Noteworthy are the following: alizarine, the valuable coloring matter of madder;[68] vanilline, the aromatic principle of the vanilla bean;[69] cumarine, the aromatic principle of the tonka bean;[70] indigo, the well-known dye-stuff;[71] uric acid, an animal product;[72] tyrosin, likewise a product of the animal organism;[73] salicine,[74] daphnetine and umbelliferone,[75] natural glucosides and related bodies; piperidine,[76] a constituent of pepper; and cocaine, the new anæsthetic.[77] Besides these, many syntheses have been accomplished of bodies isomeric and not identical with the natural products.

The alchemists labored to transmute base metals into noble ones, and were destined never to realize their ambitious designs. Modern organic chemists, operating on substances compared with which even the base metals are precious, produce articles more beneficial to mankind than gold itself, and at the same time gain, indirectly, no small store of the coveted metal.

The application of chemistry to physiology encounters the most complex and difficult problems in the science, and at the same time aims to accomplish the most beneficent results. "The physiologist complains that probably ninety-five per cent of the solid matters of living structures are pure unknowns, and that the fundamental chemical changes which now occur during life are entirely shrouded in mystery. It is in order that this may no longer be the case that the study of carbon compounds is being so vigorously prosecuted."[73] It may seem strange to the non-professional in this audience that, in spite of persistent and skilful attempts to solve the problem, chemists are obliged to admit ignorance of the exact composition of so common a substance as the white of egg, yet until they acquire an accurate knowledge of the constitution of albuminous substances, the processes of animal economy cannot be explained. While the physiologist, in some degree, waits on the organic chemist for further developments, the latter discovers and prepares novel bodies much faster than the physiologist ascertains their influence on the animal economy. To the joint labors of chemists and physiologists are due the blessings of anæsthetics, hypnotics, and other conquerors of suffering and disease. The anæsthetic properties of cocaine and the circumstances of their discovery are matters of popular knowledge. Within a twelvemonth, ethyl-urethane has been added to the list of hypnotics.

In recent years, sanitary chemistry has acquired great importance, and now occupies a distinctly defined field, including all that pertains to the hygienic value of foods and beverages, their adulterations and their fraudulent substitutes; questions of gas and water supply; of the uses and abuses of disinfectants; of household ventilation, and of the diverse matters grouped under the term chemical engineering. Of this very practical branch of chemical science, as well as of the valuable additions to materia medica, of the improved methods introduced into analytical chemistry, and of the ever increasing contributions to the chemistry of agriculture, no mention can be attempted.

The tendency of modern researches in chemistry is to magnify the atomic theory; the rapid accumulation of facts, the ever increasing ingenious hypotheses, the most searching examinations of co-ordinate laws, all tend to strengthen the Daltonian adaptation of the philosophic Greeks. Here and there a voice is raised

against the slavish worship of picturesque formulæ; but against the molecular theory underlying the symbolic system so depicted, few earnest arguments are advanced. The whole aim of organic chemistry is directed to the discovery of the arrangement of atoms within the molecule, and the success obtained justifies the hypothesis. The edifice erected through these achievements, though young in years, is too substantial to tolerate displacement of its corner-stone. The absolute truth of the atomic theory is beyond man's power to establish. Even admitting that it necessitates absurd assumptions, it is, nevertheless, indisputably the "best existing explanation of the facts of chemistry as at present known."

A noteworthy feature of existing chemical research is the recognition of the necessity of a more intimate knowledge of the connection between physical characters and chemical constitution. In the past, chemists increased the number of new compounds so rapidly, that they often neglected detailed examination of their physical properties, their relations to known bodies and to each other, preferring to satisfy their ambition by fresh discoveries. This race after new bodies still continues, but parallel with it are zealous investigators striving after a knowledge of the innate qualities and bearings of these same bodies; and the latter class of students is gaining prizes no less valuable than those secured by the former.

Chemists are also recognizing the necessity of a more minute study of the simpler phenomena of chemistry, and it is in this direction they look for many laurels in the future. Priestley's day of great discoveries by the simplest means has in one sense passed; the opportunities for isolating nine new gases, or of recognizing by chemical tests half a dozen new elementary bodies in the space of a life-time, are gone; only by the employment of the most delicate appliances, by the closest scrutiny of phenomena and the conditions governing them, by availing themselves of all the resources of physics, by an unshrinking expenditure of time and of money, to say nothing of the necessity of trained mental powers of no low order and of skilled hands, shall chemists in succeeding generations realize their ambitious designs.

NOTES AND AUTHORITIES.

(1.) The membership in these societies is distributed as follows:

Deutsche chemische Gesellschaft zu Berlin,	2,950
Society of Chemical Industry (England),	2,000
Chemical Society of London,	1,500

Société chimique de Paris,	560
Institute of Chemistry of Great Britain and Ireland,	430
American Chemical Society,	250
Society of Public Analysts (England),	180
Chemical Society of St. Petersburg,	160
Associazione chimico-farmaceutica fiorentina,	*200
Chemical Society of Tokio, Japan,	83
Chemical Society of Washington, D. C.,	48
Association of Official Agricultural Chemists (U. S. A.),	17
Total,	8,378

(2.) *New Elements Announced Since 1877.*

DATE.	NAME.	SOURCE.	DISCOVERER.
1877.	Davyum,	Platinum ores,	Sergius Kern.
	Neptunium,	Columbite,	Hermann.
	Lavœsium,	Pyrite,	Prat.
	Mosandrum,	Samarskite,	J. L. Smith.
1878.	"New earths,"	Unnamed mineral,	Gerland.
	Philippium,	Samarskite,	Delafontaine.
	Decipium,	Samarskite,	Delafontaine.
	Ytterbium,	Gadolinite,	Marignac.
	"X,"	Gadolinite,	Soret.
1879.	Scandium,	Gadolinite,	Nilson.
	Norwegium,	Gersdorffite,	Dahll.
	Samarium,	Samarskite,	Lecoq de Boisbaudran.
	Uralium,	Platinum,	Guyard.
	Barcenium,	Misapprehension,	Editor Wagner's Jahresb.
	Thulium,	Gadolinite,	Cleve.
	Holmium,	Gadolinite,	Cleve.
	Columbium,	Samarskite,	J. L. Smith.
	Rogerium,	Samarskite,	J. L. Smith.
	Vesbium,	Lava,	Scacchi.
1880.	Comesium,		Kaemmerer.
	$Y\alpha$ and $Y\beta$,	Gadolinite,	Marignac.
1881.	Actinium,	Zinc ores,	Phipson.
1882.	Di β,	Gadolinite,	Cleve.
1883.	Nameless,	Platinum ores,	Th. Wilm.
1884.	Idunium,	Lead vanadate,	Websky.
1885.	Neodymium,	Didymium,	Welsbach.
	Praseodymium,	Didymium,	Welsbach.
	$Z\alpha$,	Didymium,	Lecoq de Boisbaudran.
	$Z\beta$,	Didymium,	Lecoq de Boisbaudran.
1886.	$Z\gamma$,	Terbia,	Lecoq de Boisbaudran.

* Estimated. Many chemists are members of several of the above societies, but against this duplication may be set those not connected with societies.

(3.) Chem. News, XLVII, 261 (1883).

(4.) Chem. News, LI, 301 (read to Royal Society, June 18, 1885).

(5.) Comptes rendus, C, 1437 (June 8, 1885).

(6.) F. W. Clarke. A Re-calculation of the Atomic Weights. Part V, Constants of Nature. Smithsonian Institution. Washington, 1882.

(7.) L. Meyer und K. Seubert. Die Atomgewichte der Elemente aus den Originalzahlen neu berechnet. Leipzig, 1883.

(8.) Ber. d. chem. Ges., XVIII, 1089 (1885).

(9.) Am. J. Sci. (3), XXVI, 63 and 310 (1883).

(10.) John A. R. Newlands. On the Discovery of the Periodic Law, and on Relations among the Atomic Weights. London, 1884.

(11.) Liebig's Annalen. Suppl., Bd. VIII, 133. Also Chem. News, XL and XLI.

(12.) Ber. d. chem. Ges., XIII, 1439.

(13.) Chem. News, XLI, 83.

(14.) Sestini. Gazz. chim. ital., XV, 107.

(15.) Thomas Carnelley. Ber. d. chem. Ges., XVII, 2151 and 2287.

(16.) Nature, XXXII, 539 (1885).

(17.) Proc. Roy. Soc., XXVIII, 159, and XXIX, 247 and 266.

(18.) Pop. Sci. Monthly, New York, Feb., 1876, p. 436.

(19.) Chem. News, LII, 49 (1885).

(20.) Chem. News, LII, 34 (1885).

(21.) Ann. chim. phys., XXIII and XXIV (1823).

(22.) Ber. d. chem. Ges., XVII and XVIII.

(23.) Am. Chem. J., VII, 189 (1885).

(24.) Chem. News, XX, 271.

(25.) Nature, XXVIII, 551, and Chem. News, XLVI, 151.

(26.) Chem. News, LI, 150 (1885).

(27.) Chem. News, LII, 135 (1885).

(28.) Meyer und Langer. Pyrochemische Untersuchungen. Leipzig, 1885.

(28A.) Wurtz Dictionnaire, I, 220.

(29.) Comptes rendus, XX, 817 (1844).

(30.) Chem. News, LI, 27.

(31.) Cf. Pattison Muir. Principles of Chemistry. Cambridge, 1884.

(32.) Chem. News, XLVI, 151.

(33.) Ber. d. chem. Ges., XVIII, 1890 (1885).

(34.) Since writing the above, Dixon has read another paper on the subject, in which he rejects Traube's views. Nature, XXXIII, 286 (1886).

(35.) The decomposition of potassium chlorate affords another case in point. The exact manner in which heat affects this salt is yet under discussion. See Dr. Teed's results in Chem. News, LII, 248 (1885), and LIII, 56 (1886). And compare Maumené, Bull. soc. chim., XLV, 51 (1886).

(36.) Wurtz Dictionnaire de chimie, art. *Affinité*.

(37.) Proc. Roy. Soc., XIX, 498.

(38.) Proc. Am. Assoc, Adv. Sci., XXXIII, 185 (1884).

(39.) *Idem*, p. 141. Cf. R. B. Warder. Proc. Am. Assoc. Adv. Sci., XXXII, 156.

(40.) Wurtz Dictionnaire, art. *Thermochimie.*
(41.) Essai de mécanique chimique. Paris, 1879, 2 vols.
(42.) Thermo-chemische Untersuchungen. Leipzig, 4 vols., 1882–86.
(43.) J. W. Langley. Proc. Am. Assoc. Adv. Sci., XXXIII, 153.
(44.) Pattison Muir. Principles of Chemistry. Cambridge, 1884, p. 3c6
(45.) Comptes rendus, LXXXV, 1214 and 1220.
(46.) Ann. chim. phys. [5], XV, 132.
(47.) Comptes rendus, XCVI, 1140 *et seq.*, and Chem. News, XLIX, 13. Also Comptes rendus, XCVIII, Jan. 28, 1884.
(48.) Olzewski. Comptes rendus, C., Feb. 9, 1885.
(49.) Chem. News, LII, 201 (1885).
(50.) Fleitman in 1879. Cf. Chem. News, L, 3 (1884).
(51.) Dingler's polyt. J., 1882.
(52.) Nature, XXXII, 354 (1885).
(53.) Chem. News, XLVII, 67, and L, 41.
(54.) Nature, XXXII.
(55.) Liebig's Annalen, CCXX, 168.
(56.) Protok, Russ, phys. chem. Ges., 1884, 458.
(57.) Report on Glucose, prepared by the National Acad. Sci. U. S. Internal Revenue. Washington, 1884.
(58.) Sorghum, its Culture and Uses. Press of the Chamber of Commerce. New York, 1885.
(59.) Sugar Industry of the United States. Dept. Agriculture, Chemical Division, Bulletin No. 5. Washington, 1885.
(60.) Notes on the Literature of Explosives, in Proceedings U. S. Naval Institute, Nos. 20, 21, 22, 24, 27, 29, 32, 33.
(61.) Trans. Roy. Soc. Edinburgh, XVI (1849), and XX (1851).
(62.) Ber. d. chem. Ges., XVII, 514 (1884).
(63.) *Idem*, XV, 2893, and XVI.
(64.) Zeitschr. f. chem., 1871, 117.
(65.) Ber. d. chem. Ges., XV.
(66.) Journ. Chem. Soc., London, 1885.
(67.) Naturwiss. Rundschau, I, 1 (1886).
(68.) Graebe und Liebermann. Liebig's Annalen, Suppl. Bd., VII, 300.
(69.) Tiemann, Ber. d. chem. Ges., VII, 613.
(70.) Perkin, Liebig's Annalen, CXLVII, 230.
(71.) Baeyer, Ber. d. chem. Ges., III, 515.
(72.) Horbaczewski, Ber. d. chem. Ges., XV, 2678.
(73.) Erlenmeyer und Lipp, Ber. d. chem. Ges., XV, 1006 and 1544.
(74.) Arthur Michael, Am. Chem. J., V, 171.
(75.) von Pechmann, Ber. d. chem. Ges., XVII, 929.
(76.) Ladenburg und Roth, Ber. d. chem. Ges., XVII, 514.
(77.) Merck, Ber. d. chem. Ges., XVIII, 2264.
(78.) Dr. Armstrong.

LUMINIFEROUS ÆTHER.

In the preceding impression of this JOURNAL, page 129, Prof. Pliny Earle Chase writes as follows: "Prof. De Volson Wood writes under the same misapprehension, overlooking the precaution which Herschel had taken to define his hypothesis, 'that an amount of our ethereal medium equal *in quantity of matter* to that which is contained in a cubic inch of air (which weighs about one-third of a grain) were enclosed in a cube of an inch in the side.'" I do not understand how Professor Chase could, deliberately, make this charge of overlooking Herschel's hypothesis in the face of the fact that in the immediate connection of my reference to Herschel's computation, I stated (*Phil. Mag.*, 1885, p. 390): "But his analysis was founded upon the *assumption* that the density of the æther was the same as that of the air at sea-level."

The closing paragraph of Professor Chase is questionable as to the correctness of the facts.

The temperature of space is, at the present day, generally assumed to be much less than the lowest temperature yet produced by artificial means; and it is interesting to note the efforts made to produce extreme cold. Stewart on "Heat," p. 110, gives an example in which a temperature of — 140° C. (— 220° F.), was obtained, but very recently (Van Nostrand's *Eng. Mag.*, xxxv, p. 87), in solidifying oxygen, a temperature of — 200° C. (— 330° F.) is said to have been produced, which is only 131° F. above absolute zero.*

DE VOLSON WOOD.

MODIFICATION OF PLANTS BY CLIMATE.—Mr. A. A. Crozier, of the University of Michigan, has published a thesis bearing this title. It has brought together a great amount of scattered material upon this interesting subject and, not the least valuable part of the paper, a full bibliography is given. Summing up the whole matter, the conclusion reached is as follows: "It seems to be established that as plants move from the locality of their largest development toward their northern limit of growth they become dwarfed in habit, are rendered more fruitful, and all parts become more highly colored. Their comparative leaf surface is often increased, their form modified, and their composition changed. Their period of growth is also shortened and they are enabled to develop at a lower temperature."—*Botan. Gazette, Sept. and Oct., 1885.*

[* See this JOURNAL, *ante* art., BOLTON, p. 213.—COM. PUBL.]

THE "NOVELTIES" EXHIBITION OF THE FRANKLIN INSTITUTE, 1885.

ABSTRACTS OF REPORTS OF THE JUDGES.

(Continued from page 149.)

GROUP II*a*.—TRANSMISSION OF POWER.

Judges:—J. J. De Kinder, *Chm.;* Thos. W. Jenkin, Geo. A. Vaillant, Strickland Kneass, S. Lloyd Wiegand, Wm. Harkness, Jr., Wilfred Lewis, Oberlin Smith.

ALEXANDER BROS., PHILADELPHIA.

Leather Belting.—This exhibit is a double leather belt, 32 inches wide by $\frac{7}{16}$ inch thick, made in such a manner as to equalize the working strain over the entire width of belt and give the maximum surface of contact with the pulley. In a hide of leather, that part which lies immediately over the back bone will stretch less than any other, and cause a tight line in the belt cut from it. It is usual in wide belting to cut the hide so that the tight line shall come in the centre of the belt, and consequently the edges of such belts are loose and do but a small portion of their share of duty.

To overcome this difficulty, the belt under consideration is made double and built up so that the tight and loose lines in one layer come opposite the loose and tight lines in the other, thereby making it of homogeneous strength and elasticity, and giving it a uniform tension over its entire width. The belt ran very straight upon the pulleys and showed upon its surface that contact occurred as claimed. We commend the material and excellent workmanship.

(*Honorable Mention.*)

THEO. BERGNER, PHILADELPHIA.

Duplex Hangers.—"In these, both journals of a counter-shaft are carried in a bow-shaped casting, which, while supporting the shaft at two points, the proper distance apart, is itself supported in a single ball or socket bearing, about which the whole shaft may be adjusted by unskilled hands, and then securely held in place by a single clamping-bolt. Another feature (applicable to both single and double hangers) provides for adapting the same hanger either

for suspension vertically or for lateral fastening to a post or wall. On loosening a single screw, the position of the journal box, oil dish and belt-shifter arm can be instantly so reversed as to change the conditions from those of a drop hanger to those of a bracket hanger or vice-versa." These hangers are well designed for their purposes and will evidently accomplish all that is claimed.

(*Honorable Mention.*)

BREHMER BROTHERS, PHILADELPHIA.

Specimens of Bevel Gearing.—The gearing on exhibition consists of a train of bevel wheels and pinions so accurately cut and fitted that the lost motion in the entire train is scarcely perceptible.

This is accomplished without producing any stiffness or irregularity in the action of the teeth, and even when working under pressure, it is impossible to detect any roughness in the motion. The teeth are cut on a special machine designed by Mr. Hugo Bilgram, in which he has made an ingenious application of the principle that teeth which gear correctly with any given rack will gear correctly with each other. They are all evolute in shape, and are actually cut out of the solid by a process of rolling which forces the wheel or pinion to pass under a reciprocating tool corresponding to a rack tooth.

It is, of course, necessary to form each side of the tooth separately, and the practice is to take two roughing and two finishing cuts on each wheel. By a suitable mechanism, the wheel is made to roll under the cutting tool. and the result is a conical surface of mechanical perfection, formed in a novel and ingenious manner by the action of a straight cutting edge. Mathematically speaking, this surface is pyramidal and tangential internally to an evolute from the rolling cone, but, from a practical point of view, the pyramid could not be distinguished from the evolute itself, except in the case of a very coarse feed, taken for the especial purpose of showing the difference.

Upon this system of cutting bevel gears, the evolute is the only shape possible, because it is necessary that the edge of the tool be straight in order to produce a conical or pyramidal surface. Although some prejudice exists against this form of tooth on account of its obliquity of action, the ground for such prejudice is

really very slight, as the increase in pressure due to obliquity is never more than ·035 over that for the best cycloidal shapes.

For accuracy of form and superiority of finish, this exhibit of bevel gearing deserves the highest praise— (*A Silver Medal.*)

J. E. LONERGAN & CO., PHILADELPHIA.

Oil Cup.—This cup is composed of an outer skeleton brass frame surrounding a cylindrical glass vessel and united to it with oil-tight joints by top and bottom cork washers. The quantity of oil fed is regulated by a spindle valve, and adjusted by means of a small set-screw passing through a button on the end of the valve stem. When oil is flowing to the bearing, this set-screw rests upon a little nipple, raised about one-eighth inch above the top of cup; to stop feed, it is only necessary to raise the button and turn it a little on its axis, thereby removing the screw from its position on the nipple and allowing the spindle valve to seat under pressure of a heavy brass spring. When oil is again needed, it is only necessary to return the adjusting screw to its place upon the nipple, and the former feed will be resumed.

The principal advantages of this cup are: the facility with which the feed may be regulated; the means of quickly flooding the bearing in case it becomes heated; and the ease with which the supply of oil may be entirely cut off, or the regular feed resumed.

(*A Bronze Medal.*)

JAMES H. BILLINGTON & CO., PHILADELPHIA.

Belting.—Exhibit various widths of the well known Hoyt terne oak short-lap belting.

The leather is short-lap and oak-bark tanned, such as has been in use for nearly forty years. It is of the usual excellent quality, but presents nothing novel. (*Honorable Mention.*)

CHARLES A. SCHWEREN, PHILADELPHIA.

Leather Belting for Dynamos.—This belting is fastened with wire screws, which are forced into the leather, leaving both sides of the belt smooth. The specimen driving a Thomson-Houston dynamo runs remarkably smooth, shows little stretch, and is very pliable. The construction is decidedly novel.

(*Honorable Mention.*)

WILLIAM SELLERS & CO., PHILADELPHIA.

Line Shafting, Couplings, Hangers and Pulleys and Counter-shafting.—This exhibit shows the uniform standard of excellence in material and workmanship for which this firm is noted. The specimens on exhibition are not decidedly novel; in fact, it is doubtful whether there is room for any improvement left on these goods. Lightness combined with great strength, symmetrical lines, and first-class finish in every detail are the features.

(*Not entered for competition.*)

JOHNSON & CHRISTIAN GALLAGHER, PHILADELPHIA.

Exhibit an angular coupling joint, which shows in a general way an improvement in compactness and rigidity over similar devices. The arrangement for lubrication is novel in that centrifugal motion is made use of to distribute the lubricants from the centre. (*A Bronze Medal.*)

PHŒNIX OIL COMPANY, PHILADELPHIA.

Belt Oil.—The belts running in the Exhibition, and treated with this oil, show it to be a decidedly superior article. It prevents slipping, and does not stretch the belt as much as usual. It is highly recommended, by responsible parties using it, for its water-proof qualities.

(*Referred to the Committee on Science and the Arts.*)

GEORGE V. CRESSON, PHILADELPHIA.

Shafting, Pulleys, Hangers and Couplings.—The adjustable loose pulley arrangements shown deserve special notice. The loose pulley runs on a sleeve forming part of the hanger, and therefore independent of the shaft. On one end of the hub is a flange, also a similar one on the tight pulley; between these flanges is a rubber disc. To get the sleeve pulley in motion it is pressed by means of a lever against the tight pulley, and by frictional contact receives a rotary motion. The loose pulley revolving causes the belt to move, the automatic shifting device shifting the belt over to the tight pulley at the same time. When the belt has passed to the tight pulley, the loose pulley comes to rest, and vice-versa.

When high speed machinery is used, the economy of this device is especially valuable.

The remainder of the exhibit is more conspicuous for good workmanship than novelty. (*A Bronze Medal.*)

THE SOUTHWARK FOUNDRY, PHILADELPHIA.

Clutch Pulleys.—The friction-clutch exhibited at work consists of a device wherein all the working parts of the clutch lie equally on each side of the pulley. The two clutch segments are of the same size and weight, are carried upon the turned opposite ends of the driver, and are forced radially outwards against an internal cylindrical surface. These segments are faced with ample area of hard wood with the grain "end on." They are separably adjustable by revolving nuts, for wear and to contact with the friction surface. The segments are so placed that, to the pressure of the screws upon them, is added the effect of centrifugal force. The segments are operated by means of a toothed rack and spur pinion. The hub of the pulley is formed of two equal and opposite half-shells bolted to the ring of the pulley. All the working parts of the clutch are within the shell. The whole combination forms a well-balanced, compact clutch of great power and readily adjustable for wear. (*A Bronze Medal.*)

GROUP 11*b*.—STEAM ENGINES.

Judges:—S. L. Wiegand, *Chm.*

HENRY C. BROOMALL, PHŒNIXVILLE, PA.

Miniature Engine and Boiler.—For skilful workmanship and ingenuity— (*Honorable Mention*)

BUCKEYE ENGINE COMPANY, SALEM, O.

Buckeye Engine.—Remained in the building since the Electrical Exhibition, and was then tested with most satisfactory results. (*Not entered for competition.*)

CHRISTIANA MACHINE COMPANY, CHRISTIANA, PA.

Burnham's Automatic Engine.—For steady running at very high speeds— (*A Silver Medal.*)

COLT'S ARMS COMPANY, HARTFORD, CONN.

Colt's Disc Steam Engine.—For good workmanship and compactness— (*A Silver Medal.*)

WM. M. DEAL, PHILADELPHIA.

Balanced Slide Valve.—Not regarded as practical.

HARRISBURG CAR MANUFACTURING COMPANY, HARRISBURG, PA.

The Ide Engine.—For excellent system of lubrication, compactness, good workmanship and design— (*A Silver Medal.*)

THE KENSINGTON ENGINE WORKS, PHILADELPHIA.

Buckeye Automatic Engine.—For good design and workmanship— (*A Silver Medal.*)

THE PHŒNIX IRON COMPANY, TRENTON, N. J.

Phœnix Automatic Cut-off Engine.—For general design, simplicity of construction, good workmanship, smooth and noiseless running and excellent proportions—

(*A Silver Medal and a Reference to Com. on Science and the Arts.*)

SHIPMAN STEAM ENGINE COMPANY (C. D. YOUNG & BROTHERS), AGENTS, PHILADELPHIA.

Shipman Engine.—For perfection of automatic supply of fuel and water— (*A Silver Medal.*)

H. B. SMITH MACHINE COMPANY, PHILADELPHIA.

Portable Horizontal Engine with Upright Boiler.

(*Not entered for competition.*)

SOUTHWARK FOUNDRY, PHILADELPHIA.

Southwark Automatic Cut-off Engine.—For compactness and good proportions— (*A Silver Medal.*)

W. P. ULINGER, PHILADELPHIA.

Hydro-Extractors.—For good design and workmanship—

(*A Silver Medal.*)

ROBT. WETHERILL & CO., CHESTER, PA.

Wetherill-Corliss Engine.—For excellent workmanship—

(*A Silver Medal.*)

T. E. WINEBRENER, PHILADELPHIA.

The Davey Safety Engine.—For ingenuity and safety—

(*A Bronze Medal.*)

GROUP II*c*.—GAS ENGINES AND CALORIC ENGINES.

Judges.—James Christie, *Chm.;* Wm. M. Smith, W. H. Blake, M. D.

DICKSON MANUFACTURING COMPANY, SCRANTON, PA.

Gas Engines.—The Stockport gas engine, exhibited by the Dickson Manufacturing Company, of Scranton, Pa., consists of two cylinders placed in line with each other and connected by a "trunk," which admits of the crank-shaft and motive parts being located between the two cylinders. One of said cylinders acts as a

plunger pump, taking in air and gas during one stroke, and compressing the same on the return stroke, and delivering the gaseous mixture at the proper moment into the opposite or actuating cylinder, where it is ignited by means of an ignition slide, which carries a small volume of flame from an external gas jet, in a manner usual in other gas engines.

The makers claim for this machine, simplicity of parts, certainty of action and ease in starting. Your committee regret that they were unable, for lack of the proper apparatus, to make an efficiency test of gas engines, but see no reason to doubt that the machine described will compare favorably in economical results with any existing gas engine. The engine is so controlled by the governor that the proper amount of the gaseous mixture enters the explosion cylinder at every revolution to maintain the regulated speed of rotation.

The engine is characterized by elegance of design and simplicity of mechanical detail, and it runs with remarkable uniformity and quietness. In consideration of these points of excellence, your committee would recommend that the Stockport engine be awarded— *(A Silver Medal.)*

THE CLERK GAS ENGINE COMPANY, PHILADELPHIA.

The Clerk Gas Engine.—Of this machine two specimens were exhibited by the manufacturers. It differs from earlier forms of the gas engine in its ability to explode a charge of gas at each revolution of the engine, when the resistance requires it, to maintain the proper velocity of rotation. The operation of the machine in the most essential particulars resembles the action of the Stockport engine, above described. The principal difference consists in the office of the pump, or "displacer cylinder," and the mode of operating the same. The piston of the latter is driven by a crank on the main shaft, and placed at the proper advance of the main crank of the engine. This displacing cylinder is so connected with the main or actuating cylinder as to force a current of air through the actuating cylinder in advance of the explosive charge, thus cleansing the latter at the termination of each forward stroke.

These engines did not exhibit the same steadiness and ease of operation noted in the engine previously described—defects, however, which may have been due to imperfect foundations, and less

perfect workmanship. For novelty and ingenuity of design, the committee recommend that the "Clerk Gas Engine" be awarded—

(*A Bronze Medal.*)

THE H. B. SMITH MACHINE COMPANY, PHILADELPHIA.

Caloric Engines.—Two types of this class of engines are exhibited by the same party. Both engines are especially adapted for pumping water; one, the "Rider," and the other the "Ericsson" engine. They are both so well known and widely used, that it is unnecessary to enter into any extended description of their respective modes of operation. They are both well adapted for light work, especially of an intermittent character The makers have recently added to the machines sundry improvements, which are not of much importance in detail, yet, in the aggregate, contribute to the efficiency of the engines.

Your committee would recommend that to these engines be awarded— (*Honorable Mention.*)

THE MERCER WIRE COMPANY, TRENTON, N. J.

Spiral Springs for Engine Governors, etc.—These are especially manufactured for the above-named purpose. The makers claim that they have been able to obtain a greater uniformity of tension than has hitherto been produced in springs of their class.

It has been impossible for your committee to verify this claim, or to ascertain positively if these springs show a marked superiority over those of other manufacturers. We, however, have found the springs in service on the governors of some engines in the Exhibition, and are assured by those in charge that the springs yield excellent results. In consideration of the above, we would recommend that the manufacturers receive—

(*Honorable Mention.*)

GROUP I I*e*.—HYDRAULIC AND PNEUMATIC MACHINERY.

Judges:—Strickland Kneass, *Chm.*; Wm. H. Thorne, Wilfred Lewis, John E. Eyanson, Henry P. M. Birkinbine, Wm. M. Smith, John J. Weaver.

H. J. BERGMAN (AGENT FOR THE CLEVELAND FAUCET COMPANY), PHILADELPHIA.

Improved Beer Faucets.—The improvement claimed for this faucet consists in a small air compressor, which is so located that

its piston rod is controlled by the handle of the faucet, whereby whenever a glass of beer is drawn a corresponding amount of air is forced into the keg, thus maintaining a uniform pressure upon the beer until the keg is emptied.

It has also a draining tube attached to the tapping plug, which drops to the bottom of the keg after inserting the plug and through which the beer below the level of the faucet can be drawn.

When a cooler is used, the air compressor is placed inside, and cold air is forced into the keg, instead of the warm air of a room, or the unwholesome air from an uncleanly and poorly ventilated cellar.

With this faucet, it is claimed that the freshness of the beer is maintained until the last glassful has been taken from the keg.

It is worthy of commendation for its novelty and for accomplishing what it claims. (*A Bronze Medal.*)

H. B. SMITH MACHINE COMPANY, PHILADELPHIA.

The Boston Blower.—The exhibitors claim special superiority in its journal bearings, which are made in the following manner: Each box has in its centre a ball by which it is securely confined in the hanger, though left free to swivel when necessary; to the upper side is attached the oil cup, and to the lower side the drip cup, to catch the oil after having passed through the journal-box. All wear is upon an internal babbitted bushing, which is removable without disturbing the outside shell of the box, while the end motion is taken up by means of set-screws (provided with suitable check nuts), which press hardened steel washers against the end of the shaft; through the upper and lower sides of the bushing, grooves are planed, through which the oil passes from the cup, and running down through several small openings, lubricates the journal from many points. At the inside ends are catch chambers, which prevent the oil from escaping into the pulleys and belt, and compel it to return through the lower channel to the drip cup.

The committee fail to see anything especially novel in this arrangement, as the ball-and-socket was used in the Demphel fan and the removable babbitted bushing in the Alden and Sturtevant fans, and was abandoned by the latter some time ago.

RICHARD BEAUMONT, PHILADELPHIA.

Straight-Way Valve.—The special feature of this valve is the

sliding gate which permits the opening of a straight-way passage of the same diameter as outlets and without contraction or enlargement.

Under the centre of a cast iron body is a pocket or recess, deep enough to permit necessary travel of the sliding gate. The slide is made of cast iron and faced with brass on parts exposed to the action of the water. The lower end is bored out in line with, and same size as outlets, so that when the gate is up as far as can be drawn by the screw, the valve presents a true cylindrical opening. On this slide and above the main water way, two circular brass discs are carried on heavy bosses, and by acting against lugs on inside of body these valve discs are tightly jammed against the valve seat by the pressure of the screw. The wedge-shaped bosses on the backs of valve discs are faced with wrought iron or steel strips, as they would be subject to wear.

A plug in the bottom of the body permits the removal of sand or dirt from the pocket in case of sufficient accumulation to prevent the valves from seating.

The *Fire Hydrants* of the same inventor exhibit no especially novel features except such as may belong to above valve. They do not appear to be provided with a drip-cock of any kind to drain the stand-pipe when the valve is closed.

The disadvantages of this style of valve appear to be the application of pressure of the screw while the valves are sliding over the seat, the unequal pressure on the valve discs, and the opening of the pocket to the admission of foreign matter when the valve is part-way shut.

The committee make no recommendation in regard to *Richard Beaumont's Straight-Way Valve*, as in their opinion the only novel and meritorious feature is offset by defects in construction and design; and, although it compares favorably with other valves of its kind on exhibition, yet does not merit any special recognition.

JAMES W. BLAKEMORE, GERMANTOWN, PHILADELPHIA.

Pump Bucket.—This bucket is designed to take the place of the ordinary wooden bucket with leather flap valve.

The working parts are of brass, and consist of two rings, between which a cup leather packing is securely clamped, and a movable disc or plate acting as a check, all of which are assembled on a central iron stem. The ring forming the valve seat is provided with a cross-bar, which is tapped to receive the valve stem,

upon which it is screwed. The piston ring, which acts as a follower to secure the cup leather packing, has also a cross-bar through which the stem passes freely, and receives a clamping nut upon the end.

The piston is turned to fit loosely in the pump barrel, and the check disc is made to slide easily upon the valve stem. Although cheaply and roughly made, the bucket appears to be well adapted to its purpose. There is nothing to get out of order, and the leather packing upon which the wear will chiefly occur, is easily replaced.

The advantages claimed are that it gives a much larger waterway and freer lift to the valve, and these the committee accord, without recommendation for award.

JOHN M. CRAWFORD, PHILADELPHIA.

Gate Valve.—This consists of a segmental, parallel-faced gate of brass or cast iron, pierced by a circular orifice of the same diameter as outlets. This gate is swung on a pivot by means of a worm gearing into teeth on its periphery; when swung opposite outlets by proper rotation of the hand wheel, a continuous cylindrical passage is formed for the water; when revolved one-eighth turn, the water-way is completely closed; but it depends entirely upon the pressure of the water upon the gate to prevent leakage. The body of valve is suitably shaped to allow sufficient motion of the gate. On account of the use of a worm and the amount of leverage used, very little power would be required to open or close the valve when under pressure.

The committee make no recommendation for award, as they do not think the valve will remain water-tight, or that it possesses any advantages over those at present in the market.

J. HENRY MITCHELL, PHILADELPHIA.

Power Fans: Two Steam-Power Fans in Motion.—These are of the type designed to ventilate apartments, and in which wings are carried by arms and revolve in a horizontal plane near the ceiling. They have a means of changing the direction and force of the air currents produced, or of stilling them whilst the apparatus is in motion, by moving a button, sliding upon the lower end of the vertical shaft, which operates through links and levers attached to the wings, partially revolving them around their carrying arms. By pushing the button upwards to a stop, the advancing edge

of the wings is brought below the mean plane of revolution, thereby causing an upward air current, and by pulling the button down to its full extent the reverse action is produced. By placing the button midway between stops the wings coincide with the mean plane of revolution and no air current is produced.

Currents of more or less intensity can be had by placing the button at intermediate positions.

The committee respectfully recommend a diploma of—

(*Honorable Mention.*)

POSITIVE WATER-METER MANUFACTURING COMPANY, PHILADELPHIA.

Fluid Meter, Rotary Pump and Water Motor.—The fluid meter consists of a cylindrical drum revolving on its axis in horizontal bearings, and carried by a casing, the interior of which just clears the top quadrant of the cylindrical surface and the ends of the drum. The bottom quadrant of the interior surface of the casing is also cylindrical and is concentric with the drum, but at a distance from it equal to about one-fourth of the diameter of the drum. The side quadrants are cylindrical, but, being eccentric with the drum, form cam surfaces extending between the top and bottom quadrants. The entrance and exit for the water are narrow openings, extending the entire length of each of these eccentric quadrants. The drum is provided with two diametrical slots at right angles to each other, into each of which a hard-rubber blade is fitted so as to slide freely and independently. Each blade fits closely to the end surfaces of the casing, but is shorter than the diametrical distance between the cylindrical surfaces. A worm is cut on one end of the axle of the drum, which gives motion to a counter for registering the number of revolutions or gallons, or cubic feet, which have passed through the meter. As the drum revolves, the blades are pushed out by the eccentric surfaces, and while moving out, pass the entrance and exit orifices and have the same pressure on both sides of them, thus being free to slide easily. It is claimed that after they pass the horizontal position, the action of gravity and centrifugal force hold them in close contact with the working surface of the casing, preventing leak and loss. A report of tests made by the Philadelphia Water Department was furnished, which makes an excellent showing. In this test, ten newly manufactured meters were tried at water pressures varying from twenty to forty-

five pounds. The greatest error was the indication of 1·378 per cent. less than the exact amount of water that passed. The average of all the errors was 0·648 per cent. The percentage of error appears to increase with the water pressure. It is claimed that the meter will continue to work and to record properly as the head of water is reduced until it reaches two inches, when the meter stops, but if the head is then increased to three inches, the meter will start again. It is also claimed that the resistance offered by the meter to the flow of water is no more than would be caused by a one-quarter bend in the pipe. We had no means of verifying this. The behavior of the meter under continued use is not yet determined, but we see no reason to believe that it will deteriorate to any considerable extent. The parts are well designed and proportioned, and the workmanship superior. (*A Silver Medal.*)

(*To be continued.*)

BOOK NOTICE.

Electric Transmission of Energy, and its Transformation, Subdivision and Distribution. A Practical Handbook. By Gisbert Kapp, C. E., Associate Member of the Institution of Civil Engineers, Associate of the Society of Telegraph Engineers and Electricians. New York: D. Van Nostrand.

It is easy to predict that this book will be widely read by more than one class of readers. Students and instructors in electrical engineering will find in it much that is suggestive as to method of treatment, while those engaged in practical work will find it equally helpful in securing clear notions of the complicated relations there presenting themselves. Even enterprising managers of manufacturing interests may receive valuable suggestions as to the feasibility of using electric wires and motors, instead of shafts, pulleys, belts and cog gearing: and yet, the book is not one of those mere popular treatises that talks round about the subject without saying anything that can be computatively applied.

Starting with a rapid review of elementary principles and the absolute system of measurement, the author is at once able neatly to develop the simple equations for the transmission of energy by means of "the ideal" dynamo and motor consisting of a simple "slider." From the slider to the rotary form is an easy step; and thus he shows the power of the modern method in rapidly furnishing a first approximation to the facts, and by a few changes, the more rigorous expressions for the electrical energy developed in the rotation of any form of armature, as well as the efficiency of the conversion.

Perhaps the only caution to be suggested concerning these early chapters is that of regarding "Professor Hughes' Theory of Magnetism," as propounded by the author, page 15, *et seq.*, as due to Professor Hughes. It is

not easy to excuse such insularity in one who, like our author, seems to be somewhat familiar with German scientific literature, and who should consequently have known this theory as developed with precision by Weber and Wiedemann, some years before Professor Hughes proposed a new "theory of magnetism." Let the lucid sincerity of Mr. Kapp's style, however, assuage the critical temper!

The author's method of treating the magnetic circuit and field will excite some interest. By means of Faraday's notion of the conduction of lines of magnetic force, a magnetic circuit may be treated in a manner similar to an electric circuit; the strength of field produced being considered as varying directly as the "magneto-motive force," and inversely as the "magnetic resistance." Mr. Kapp's method reminds one of the development of this conception given by Rowland and Bosanquet, and the form of expression given by the author for the number of lines of force in the magnetic field is very similar to that proposed by Rowland at the Philadelphia Electrical Conference of 1884. We cannot help thinking that it would have added considerable to the value and interest of the author's empirical formula, if the method of determining its constant had been fully stated.

The best part of two chapters is devoted to an explanation of the graphic methods used in determining the peculiarities of dynamos and motors, and their efficiency under varying conditions. Then follows a discussion of the two great systems of transmission; namely, at constant pressure, and at constant current; not neglecting the line itself and the important economical formulæ and tables worked out by Sir Wm. Thomson, and by Professor George Forbes in his admirable Cantor Lectures; while the two kinds of circuits, aërial and underground, and their mechanical details are also discussed in relation to the various kinds of transmission.

One of the most interesting chapters to most readers, probably, will be that in which the author reviews, and states the results of the admirable prize essay of A. Beringer, entitled *Kritische Vergleichung der Elektrischen Kraftübertragung mit den gebräuchlichsten Mechanischen Uebertragungssystemen.* The thoroughness and scientific comprehensiveness of Herr Beringer's essay render this English excerpt of the results of the comparison of electric, hydraulic, pneumatic and wire-rope transmission quite to the point, in the absence of a complete translation.

After the general discussion of the problem of electric transmission, the author presents a brief classification of the various actual forms of generators and receivers. The concluding chapters are devoted to a statement of the prominent examples of the use of electricity in operating cranes, pumps, fans, railways—not omitting the telpherage system of Professor Jenkin—and closing with a description of the experiments and devices pertaining to high-pressure and long-distance transmission.

In concluding, we cannot feel that we have done justice to our author in these cursory remarks without alluding to the general readableness of the volume. There is a graceful originality, as well as ability of statement, running through the book that emphatically disposes one to class it among the more useful works in applied electricity.

M. B. S.

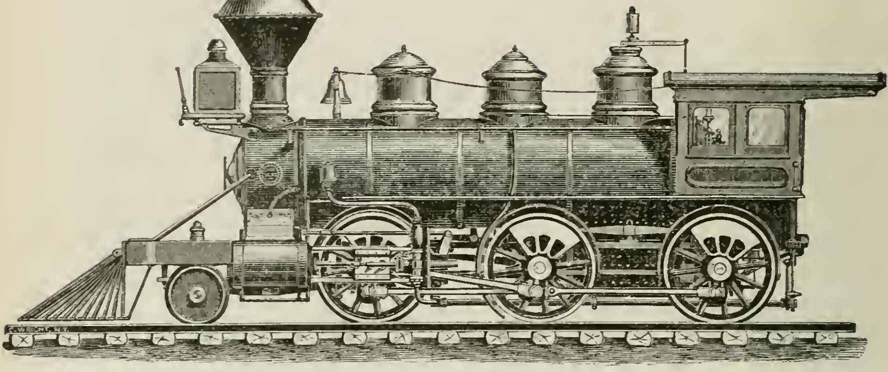


Fig. 16.

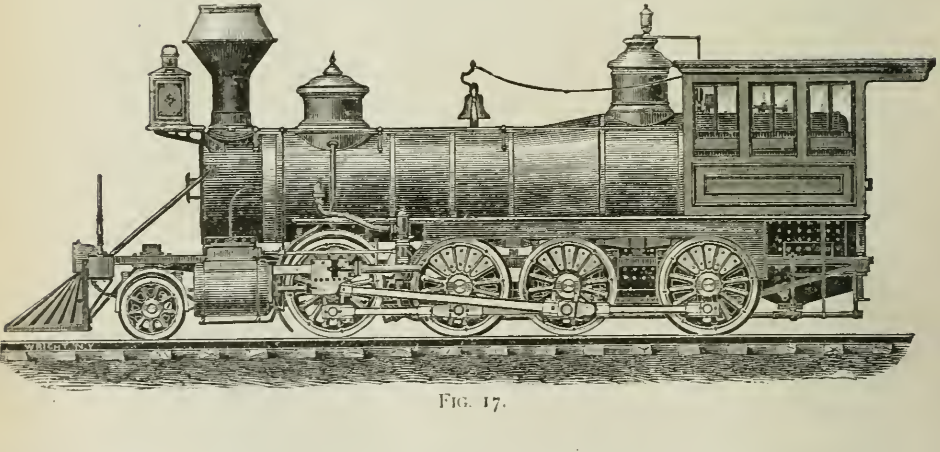


Fig. 17.

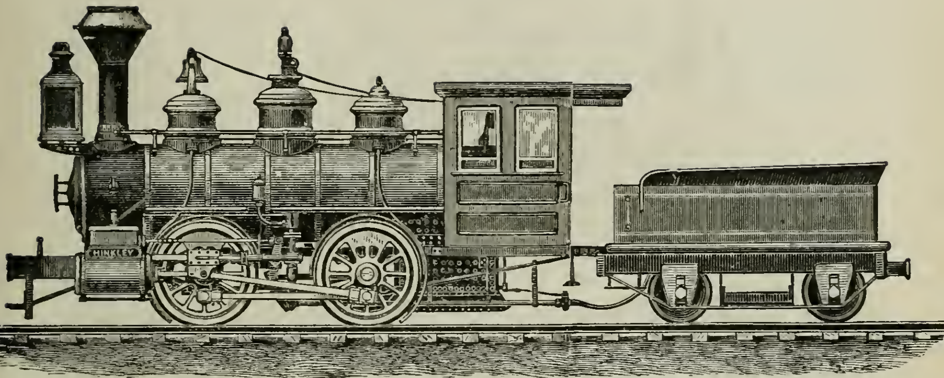


FIG. 19.

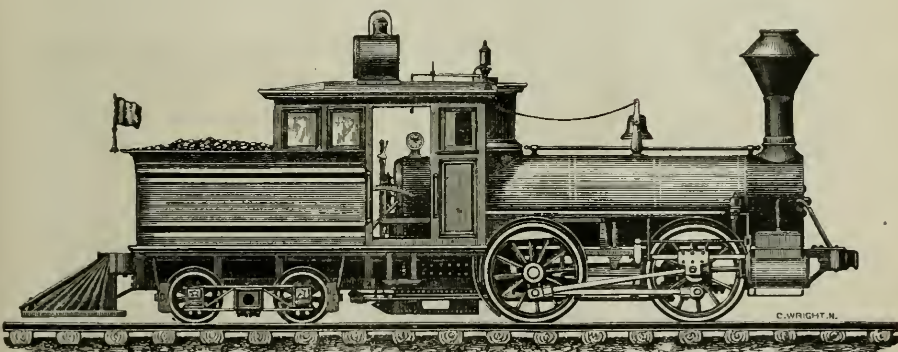


FIG. 20.

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The EVOLUTION of the AMERICAN LOCOMOTIVE.

By M. N. Forney.

[*A Lecture delivered before the* Franklin Institute, *January 8, 1886.*]

Ladies and Gentlemen:—In the historical accounts of railroads which have been written, and which have generally been very incomplete, the process of development through which this wonderful machine was perfected in America, has never been adequately told. To do it, however, it will be essential to begin—as personal history often does—with European ancestors. It is hardly worth while, though, to repeat the history, which has been told so often, of the inventions and works of Watt, Murdock, Oliver Evans, Trevithick, Blenkinsop, Chapman, Ericsson, Stephenson and others, who are mentioned in connection with the early days of the iron horse, when it was still a mere colt. Their work, important as it was, will be passed over, as it is the purpose of the lecture to describe not how the locomotive was born, but how it grew and developed in America, after it made its early appearance on the English railroads. We will begin with the celebrated trial on the Liverpool and Manchester Railway, in 1829.

In that year, it was determined by the Director of that company to offer a premium for the best locomotive engine, which should draw, on a level plain, three times its own weight at ten miles per hour. Mr. D. K. Clark, in his treatise on *Railway Machinery*, says very truly, that "from this time, 1829, may be dated the era of modern locomotives in England," and, it may be added, in the world.

The most successful locomotive in that trial, as probably most of you remember, was the "Rocket" (*Fig. 1*), built by Robert

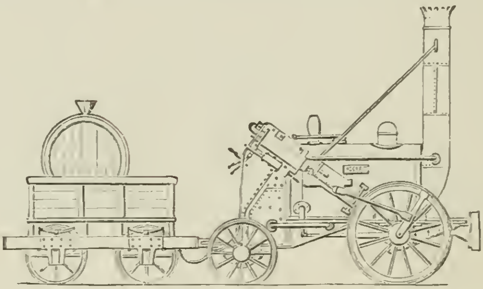


FIG. 1.

Stephenson, of Newcastle. This was the first locomotive made in England with a multitubular boiler. The trial demonstrated the superiority of that form of boiler over all others for locomotives, and it has maintained its pre-eminence ever since, with very little or no change in the principles of its construction. The value of that form of boiler, and the great advantage of the steam blast in the chimney, were established by that trial beyond all question, and all subsequent experience has confirmed this early verdict in their favor.

But before we go further, perhaps a little explanation should be given of the principles and of the construction of multitubular locomotive boilers, and some of the reasons why they are made as they are, will be presented.

You are all familiar with the ordinary phenomenon of a boiling tea kettle. In the days of our grandmothers, the method employed for boiling water was to suspend an iron or a copper kettle and then build a fire under it. Modern progress has substituted a cooking stove, with a round or oblong hole on top, over which the kettle is placed, the fire being below. You all know,—especially the ladies present, who, it is hoped, are not ignorant of such

subjects,—that cooking stoves, besides a kettle of moderate size, also have, what in domestic parlance is called a wash-boiler, which holds a very much larger quantity of water than the smaller kettle. The opening in the stove, which receives the wash-boiler, is usually oblong and much larger than that which takes the tea kettle, consequently the amount of surface in the bottom of the large kettle or boiler, which is exposed to the fire, is much greater than that of the small kettle. Experience has taught the need of this; that is, if a large amount of water must be boiled, a proportionate amount of surface of the kettle must be exposed to the fire. Or, in other words, each square inch of surface of the kettle will absorb a certain amount of heat and convey it to the water inside. Consequently, if much water is to be heated, there must be much surface exposed to the fire, because two square inches will absorb twice as much heat as one, and ten square inches ten times as much. The same principle which is applied to cooking stoves holds good also of locomotive boilers. In a locomotive, a large amount of water must be boiled and converted into steam in a short time, and the amount of space which can be occupied by the boiler is limited. The problem, in the construction of locomotives, then, was to make a boiler of a given size with the largest possible amount of surface exposed to the fire.

To meet these conditions in the "Rocket," Robert Stephenson designed a rectangular fire-place or fire-box, as it is technically called, made of metal plates, and this box had double sides and a double top, with a space between, which was filled with water. The fire was, therefore, surrounded with water, and the heat was rapidly absorbed by the plates from the fire on the one side and conducted to the water on the other.

But mention has been made of the steam blast. This is produced by allowing the exhaust steam from the cylinders to escape up the chimney. The effect is to drive the smoke and gases up the chimney, which produces a partial vacuum below. The air and smoke has a tendency to flow into this vacuum, which creates a strong draft through the fire and stimulates the combustion in the grate. When a locomotive is working hard, the air is drawn through the fire and the products of combustion are carried away from it and up the chimney very rapidly; the consequence is that there is very little time for the heat to be conveyed to the sur-

faces of the boiler. For this reason, a large number of small tubes are provided, through which the smoke and gases escape. These present a great deal of surface and are surrounded with water. The heat is thus absorbed in the inside of the tubes and communicated to the water on the outside. By this means, a large amount of what is called heating surface is provided, and, consequently, a great deal of water can be heated and converted into steam.

As already stated, one result of the trials on the Liverpool and Manchester Railway, in 1829, was that the great advantage of the multitubular boiler and the steam blast was demonstrated, and these features of locomotive construction have been in use ever since. We may then mark and emphasize this as a distinct step in the evolution of the locomotive, and we may now inquire what was the next step. Neither of the two other locomotives, the "Sanspariel" and the "Novelty," which took part in the Liverpool and Manchester trial, had any distinct features, not embodied in the "Rocket," which have survived to the present time. We may, therefore, disregard them, and see what modifications were adopted in the engines which succeeded the "Rocket." In Clark's *Railway Machinery*, it is said that "the first eight engines made by Mr. R. Stephenson for the Liverpool and Manchester Railway, were made on one general plan: four-wheel engines, tall and square, with outside cylinders in an inclined position, and working on crank-pins fixed to the driving-wheel. These engines, from their shortness and from the extreme transverse distance of the cylinder, were susceptible, at high speeds, of a violent oscillating motion, which eventually led to their abandonment."

Previous to 1830, Mr. Hackworth designed a four-wheeled engine for the Stockton Railway, with cylinders inside of the wheels and connected to cranks on the driving-axles; the four wheels were coupled together. In the early part of 1830, Mr. Berry also completed a locomotive of a similar design.

In the latter part of 1830, Mr. Stephenson built the "Planet" (*Fig. 2*), which gave its name to a whole class of engines afterwards. It had four wheels, two of which were drivers. The axles were both located between the fire-box at one end and the smoke-box at the other. The cylinders were placed in the inside of the wheels, and were connected to cranks on the driving-axle. The

cylinders of the "Rocket," as you will observe, were on the outside of the wheels, and occupied an inclined position, and one of the axles was behind the fire-box. The "Planet" engine was the combination, in part, of what had previously been known; the multitubular boiler, the blast pipe, the inside horizontal cylinders, which were placed inside the smoke-box, and the double crank-axle. It had no special features of novelty, but it represented a distinct type which was much used and was a definite step in advance. As Clark says, "the success of the arrangements combined in the 'Planet,' formed a new starting point for improvement. New locomotives were from that time formed on the model of the inside-cylinder engine, and the pattern was early imitated on other railways."

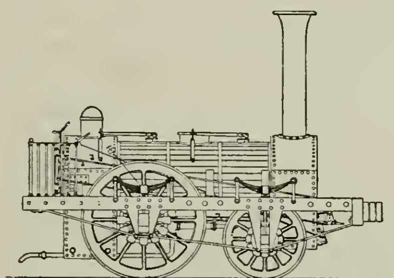


FIG. 2.

Woods's *Treatise on Railways*, published in 1838, contains a list of locomotives—beginning with the "Rocket"—built by R. Stephenson & Co. for different railroads. Among them are three for the Newcastle and Frenchtown Railroad in this country, two for the Saratoga and Schenectady, three for the Mohawk and Hudson, one for New York, one for the United States, three for the Charleston and Columbia, two for the Pennsylvania, one for Columbia, making sixteen locomotives in all which were sent to this country previous to 1838. Those sent to the Newcastle and Frenchtown Railroad, and the first ones sent to the Saratoga and Schenectady and the Mohawk and Hudson Railroad, were four-wheeled engines, and were, in all probability, of the "Planet" class. The wheels of these engines were near together, and as the wheel-base was short, they were unsteady on our rough roads. The axles were held rigidly parallel to each other, and therefore there was a lack of horizontal flexibility. To obviate these difficulties, Mr. Horatio

Allen, in a report made to the South Carolina Railroad Company, in May, 1831, made the following suggestions: "As to the change of direction, horizontally, as in the entrance of turn-outs and the passage of curves * * if we connect the frame with the cross-piece only at the centre, and by a horizontal joint the two sets of wheels will thereby be enabled to pass all curvatures with the facility of two simple wagons connected in the ordinary manner."

In the latter part of 1831, Mr. John B. Jervis recognized the defects of the English engines of the "Planet" class, which had been imported into this country for the Mohawk and Hudson Railroad, and then invented what he called "a new plan of frame, with a bearing-carriage, for a locomotive engine." He described this invention, in a letter to the *American Railroad Journal*, as follows: "The leading objects I had in view, in the general plan of the engine, did not contemplate any improvement in the power over those heretofore constructed by Stephenson & Co., but to make an engine that would be better adapted to railroads of less strength than are common in England; that would travel with more ease to itself and to the rail on curved roads; that would be less affected by inequalities of the rail, than is attained by the arrangement in the most approved engines." Mr. Jervis's engine is represented by *Fig. 3*, from which it will be seen that the driving-

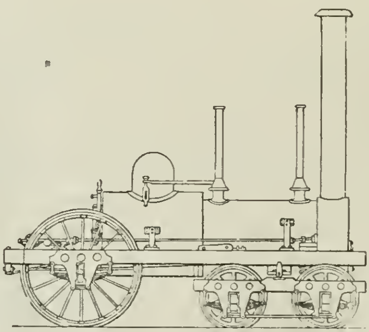


FIG. 3.

wheels were placed behind the fire-box and boiler. Other locomotives were built soon after with the driving-wheels in front of the fire-box, as shown in *Fig. 4*. The difficulty with these two classes of engines was that the driving-wheels carried too small a proportion of the weight when they were behind the fire-box, and

they had too much on them when they were in front. To obviate the latter difficulty, the locomotive shown in *Fig. 5* was con-

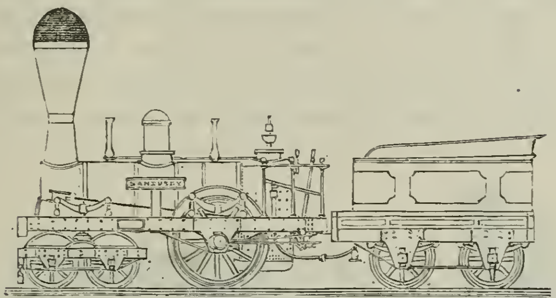


FIG. 4.

structed, with a pair of trailing-wheels behind, which thus diminished the load on the driving-wheels; it also lessened their adhe-

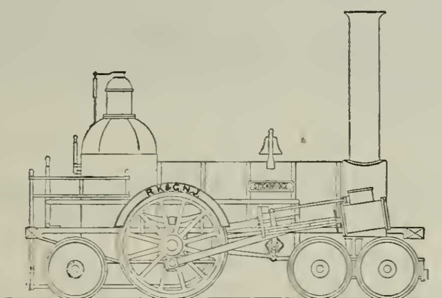


FIG. 5.

sion or the friction of their wheels on the rails, and thus made them liable to slide their wheels. In 1836, Mr. Henry R.

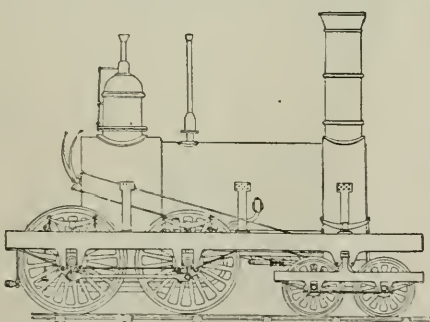


FIG. 6.

Campbell, of this city, patented the duplication of the driving-wheels, as show in the illustration, *Fig. 6.* That is, he placed one

of the driving-axles in front of the fire-box and another one behind, with a swivelling-truck in front. He subsequently constructed an engine on this plan, which was the original type of what is now called the "American" pattern of locomotive, which is now almost universally used for passenger and light freight service in this country, a late example of which is represented by *Fig. 7*.

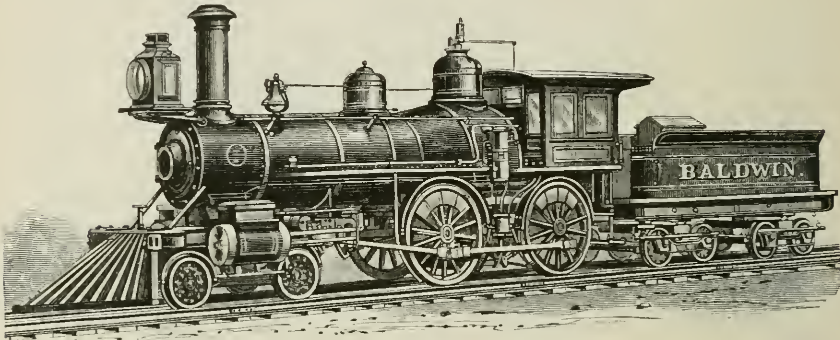


FIG. 7.

It may be well here to explain how it is that a locomotive exerts its tractive or pulling power. A wheel, as you all know, when loaded, offers a certain amount of resistance to sliding or slipping, owing to the friction between it and the surface on which it rests. This friction is in proportion to the load on the wheel. If the wheels of a locomotive are made to revolve, the whole machine moves forward, and will thus exert a tractive or pulling power, equal to the friction of the wheels on the rails. If the resistance which is opposed to the movement of the locomotive is greater than the friction or adhesion, as it is called, of the wheels to the rails, the wheels will slip, provided sufficient power is applied to them to cause them to turn. As stated before, the friction or adhesion is in proportion to the weight on the wheels. At first it may seem that to increase the capacity of locomotives to draw loads, all that we need do, would be to add to the weight of the wheels. But we can reach a limit to the weight which can be carried on each wheel. If this limit is exceeded, then the rails and road-bed are crushed, so that if we want to increase the capacity of locomotives beyond a certain point, we must add to the number of driving-wheels, so as to distribute the weight of the locomotive

on more points. It was this consideration which led Campbell to adopt two pairs of driving-wheels in connection with a truck. As traffic increased and trains became heavier, it was found, especially on steep grades, that locomotives with four driving-wheels only, were not powerful enough for the work demanded of them. This naturally led to the addition of still another pair of driving-wheels, the result of which was the ten-wheeled engine, represented by the illustration, *Fig. 8*.

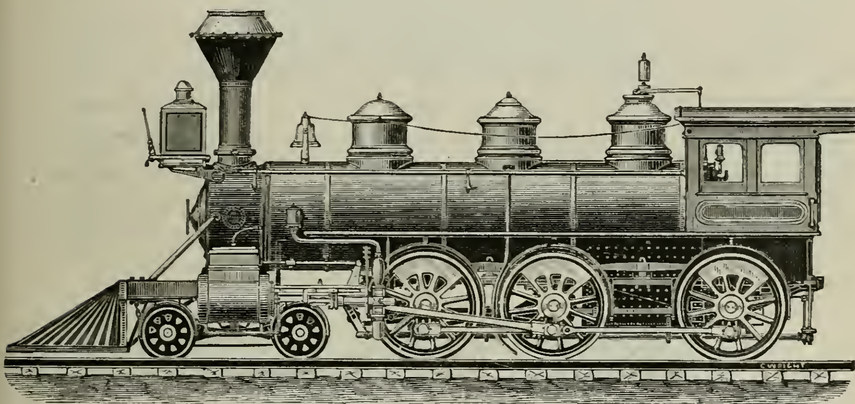


FIG. 8.

Locomotives as we find them to-day, in this country, are the result of a course of development, which has moved not in one line only. There have been different streams which have advanced for a time separately, and eventually have, as it were, flowed into each other. Thus, one of the earliest railroads in the country was the Baltimore and Ohio, and it was one of the first lines on which

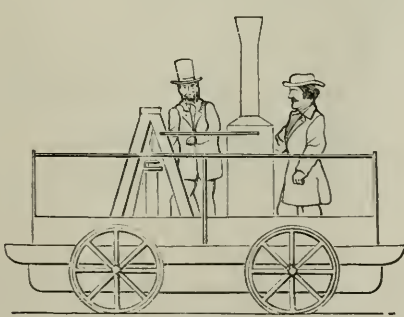


FIG. 9.

locomotives were used. As early as 1829 and 1830, Mr. Peter Cooper experimented with a little locomotive, *Fig. 9*, on that road. His

engine never advanced beyond the experimental stage, however. The story of how it ran a race with a gray horse, and was beaten by the beast, has been told a great many times and need not be repeated here.

In January, 1831, the Baltimore and Ohio Railroad Company offered the sum of $4,000 "for the most approved engine which shall be delivered for trial upon the road, on or before the 1st of June, 1831, and $3,500 for the engine which shall be adjudged the next best."

Three or four locomotives, amongst them one with a rotary engine, built by Mr. Childs, of Philadelphia, entered into the competition during the summer of 1831. The only one of them, named the "York," which proved equal to the moderate performance required of them, was the one built by Messrs. Davis & Gartner, two machinists of York, Pa. The engine had a vertical boiler and vertical cylinders, with four coupled wheels, thirty inches

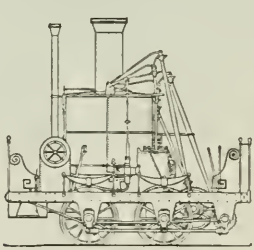


FIG. 10.

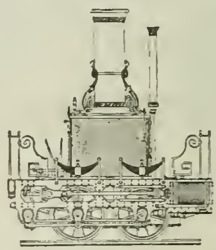


FIG. 11.

in diameter. It was altered considerably after being placed on the road. The "Atlantic" was afterwards built by the same firm, and was the first of what were afterwards known as the "Grasshopper" engines, represented by *Fig. 10*, which were used for many years on the Baltimore and Ohio Railroad. Some of these engines were still in use on that road quite recently and may be yet. Some of them were in continuous service for fifty years. Probably no other locomotive has ever been in use an equal length of time.

The "Grasshoppers" were succeeded by what was known as the "Coal-crab" locomotives, shown by *Fig. 11*. In this, the cylinders were placed in a horizontal position, and they were connected to cranks in an intermediate shaft *G*, which was geared to a second shaft *H*, which also had outside cranks to which the driving-wheels were coupled. The vertical boiler was retained in these engines.

The need of more powerful locomotives, on the heavy grades of the Baltimore and Ohio Railroad, led Mr. Winans to build some engines with eight wheels coupled, as represented by *Fig. 12.*

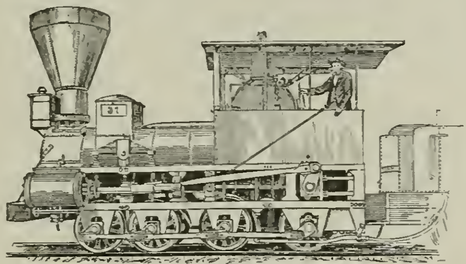


FIG. 12.

In these, the vertical boiler was abandoned, and one with horizontal tubes was substituted. The cylinders were still connected to an intermediate shaft, which was geared to one of the driving-wheel

FIG. 13.

axles. The frames, it will be noticed, were outside the wheels, a form of construction which is still retained in Europe.

These machines were ignominiously named "Mud-digger"

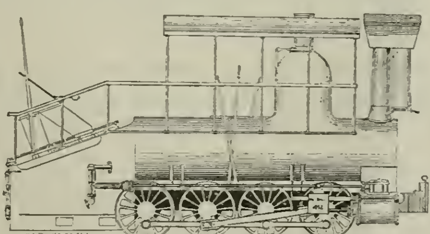


FIG. 14.

engines, and were succeeded by what was known as the "Camel" engines, two forms of which are shown in *Figs. 13* and *14*. A large number of them were built by Mr. Winans for the Baltimore and Ohio, and other roads. When these were designed, the inter-

mediate driving-shaft was abandoned, and the cylinders were connected direct to the driving-wheels. Mr. Winans was one of the earliest builders to recognize the value of a large grate and fire-box. He placed all the driving-axles between the fire-box and smoke-box, and then extended the fire-box behind the rear axle; this resulted in very great overhanging weight behind, which he balanced by the weight of the cylinders and smoke-box in front. While these engines were very long, their wheel-bases were comparatively short, and therefore they would enter and pass around sharp curves with very little difficulty. They were generally regarded as having a propensity for leaving the track at inopportune times, and this led to the adoption of a form of ten-wheeled engine, *Fig. 15*, which was designed by the late Mr. Hayes, who

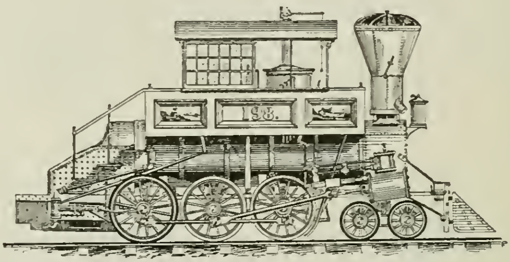


FIG. 15.

was for a number of years master of machinery on the Baltimore and Ohio Railroad. These engines had a truck in front, which extended the wheel-base, and the fire-box was made shorter than that of the "Camel" engines, so that there was less overhang behind. This type of engine was, and still is, used very extensively on the Baltimore and Ohio Railroad.

It will be seen that by two entirely different paths the locomotive developed into the ten-wheeled type, with a four-wheeled truck in front. The truck, or "bogie" system, as the English engineers call it, was for a long time a distinctive feature of American locomotives and cars. It was adopted in the first place in order to give flexibility to the machine, thus enabling it to adjust itself to the uneven and crooked roads in this country. A truck as ordinarily made, consists of two pairs of wheels, attached to a rectangular frame, which is connected by a "centre-pin" to the engine, so that the truck can turn around this pin as the front axle of an ordinary wagon swivels about its king-bolt.

It will require no explanation to show how this arrangement acts in running around curves. From the illustration of ten-wheeled locomotives, *Fig. 8*, it will be seen that one pair of the truck-wheels comes immediately behind the cylinders. This makes it essential that the front pair of driving-wheels should be placed back of the truck-wheels far enough at least to give room for the latter. The result is, that a considerable part of the weight of the locomotive rests on the truck, and the weight on the driving wheels is diminished to that extent. This lessens the adhesion of the driving-wheels, and the capacity of the locomotive to pull loads. It may be thought, at first, that a truck might be made consisting of a single axle, pivoted to the engine in the same way that an ordinary axle is attached to a wagon. It must be remembered, though, that a wagon or carriage-axle is always guided and controlled by the tongue or shafts, and if any of you have ever tried to push a carriage or other four-wheeled vehicle, when the tongue or shafts are removed, you know how difficult it is to control the movement of the front wheels and axle, and to guide the movement of the vehicle. Notwithstanding that railroad wheels are guided and kept in place on the rails by flanges, a single axle, if pivoted to a locomotive, as a wagon-axle is to a wagon, would be uncontrollable, and as our friends and fellow-citizens in New England would say, the axle would "slew" around and the wheels would not stay on the rails. To get over this difficulty, Mr. Levi Bissell invented, and in 1857 patented, a two-wheeled truck. He attached a single pair of wheels to a triangular-shaped frame and pivoted the apex of the triangle to the locomotive. The weight of the locomotive rested immediately over the axle on inclined planes, on which the locomotive frame could slide laterally. Afterwards Mr. Alba F. Smith suspended the engine over the axle by swing links, and this plan is now quite generally used.

The Bissell truck made it possible to dispense with one pair of the wheels of a truck, and the consequence was a locomotive constructed with the wheels arranged as shown in *Fig. 16*, with the front driving-wheels close to the cylinders, and with a single pair of truck-wheels on the Bissell plan in front of the cylinders. The first locomotive of this kind that was built was called the "Mogul," which gave the name to this whole class of engines, and they are now universally known as "Mogul" engines.

It will be remembered that Winans's "Camel" locomotives had eight coupled wheels. This gave them a great advantage, owing to the fact that the whole weight was on the driving-wheels, and that they therefore had the maximum amount of adhesion. Such engines would therefore pull enormous loads, but, as stated before, they were unpopular, because they were considered dangerous owing to their comparatively short wheel-base, and the large amount of overhanging weight at each end. On the other hand, the ten-wheeled engines had a considerable proportion of their weight on the trucks, which resulted in a corresponding reduction of their power. The trucks of the "Mogul" engines carried a smaller proportion of the weight, which gave them some advantage over the ten-wheeled type. Neither kind had more than six driving wheels, so that the weight which could be utilized for producing adhesion could not exceed six times that which could be carried

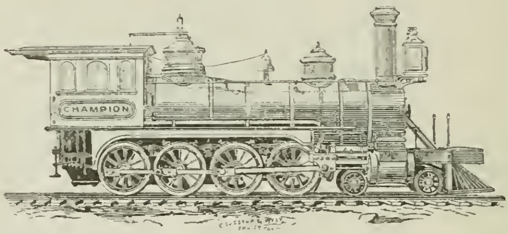


FIG. 18.

on one wheel. This naturally led to the addition of another pair of driving-wheels to the "Mogul," and the ten-wheeled engines, when more powerful locomotives were required, from which resulted the type shown by *Fig. 17*. The "Mogul" engines was thus converted into the "Consolidation" engine, and, with another pair of driving-wheels, the ten-wheeler was changed to what has been called the "Mastodon" locomotive, *Fig. 18*.

It will thus be seen that the process of evolution has developed first, what has been called the American type of locomotives, with four driving-wheels, and a four-wheeled truck, next, ten-wheeled and "Mogul" engines each with six driving-wheels, one of them with a four and the other with a two-wheeled truck; and third, the "Consolidation" and "Mastodon" engines, each with eight driving-wheels and two-, and four-wheeled trucks, respectively. These are now the principal types of locomotives on American railroads. There have

been a good many collateral branches to this family, but it will not be possible to follow out the genealogy of all of them. One branch is perhaps deserving of attention here. Even before the days of the "Rocket" and the "Planet," locomotives were built with four wheels, all drivers, and all coupled. Such machines have the advantage, that all their weight is carried on the driving-wheels, and consequently they have the maximum amount of adhesion. But, in order to pass around curves easily, such locomotives must have their wheels comparatively near together. Such engines are, therefore, lacking in stability and steadiness, especially at high speeds or on rough roads. Nevertheless, the advantage of utilizing the whole weight for producing adhesion is so great, and the evil of unsteadiness is not of much importance at slow speeds, that such engines have always been used a great deal for slow service like switching or drilling cars at stations, for urban and suburban traffic, etc. *Fig. 19* represents such a machine. It should be explained, perhaps, that all the locomotives which have been described are provided with tenders for carrying fuel and water. These tenders are coupled to engines with links and pins in the usual way. The switching engine shown by *Fig. 19*, it will be noticed, has all its weight on the driving-wheels, and therefore has the capacity of drawing a heavy load in proportion to its weight. As explained, it has the disadvantage of a short wheel-base and consequent unsteadiness. Some years ago, it occurred to the person who has the honor of addressing you, that if the frames of a four-wheeled locomotive were extended backward far enough to receive and carry a water-tank and fuel-bin, and if the extended frames were then supported on a truck, as shown in *Fig. 20*, that a locomotive of this kind would have all the advantages of the four-wheeler, and at the same time would have a long and flexible wheel-base with the consequent steadiness of the American type of engine. That is, all the weight of the boiler and machinery would be available for producing adhesion, and the engine would, at the same time, have a long wheel-base adapted for passing through curves easily, and in fact, have all the good points of the four-wheeled and the American engines combined. The plan was patented about twenty years ago, and now that the patent has expired, engines of this kind are coming into very general use. The New York and Brooklyn Elevated Railroads are equipped almost

entirely with them, and even in conservative Boston, the railroad master mechanics at a recent public meeting, declared that this kind of engine was better adapted than any other for suburban traffic.

I have now explained the successive steps by which American locomotives have advanced. I have not entered into details, but have confined myself to a description of its evolution more as a vehicle than as a machine, if such a distinction can be made. There are, however, some other features in the design and construction of American locomotives, which have had a great deal to do with their success under the conditions which they had to work. Many railroads in the country were not only very crooked horizontally, but in their early days were crooked, so to speak, vertically. The truck gave the engine flexibility laterally, but, on our rough roads, it remained to give it vertical flexibility. Campbell's first locomotive, with four driving-wheels, and a four-wheeled truck, was not successful. Its failure has since been attributed to the absence of any arrangement for equalizing the weight on the driving-wheels. Over the bearing of each driving-wheel a spring was placed which supported the weight that rested on the wheel. If one of the wheels ran over a high place on the line, the spring over the wheel was unduly compressed, and that wheel would then carry more than its proportion of weight, and the other wheels less. The reverse action would occur if any of the wheels encountered a depression in the track. On the early uneven and unballasted roads this was a matter of very great importance. The evil was probably exaggerated, too, by a lack of flexibility and elasticity in the springs. This evil led to the introduction of equalizing levers on American locomotives, very soon after Campbell's engine was constructed. These levers consist of a balance-beam or lever *A*, *A*, *Fig. 21*, which is placed between the two

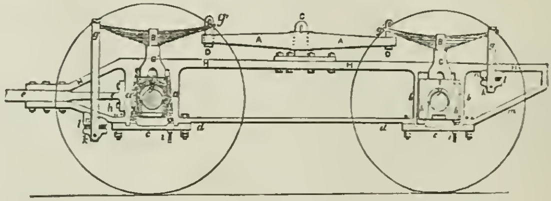


Fig. 21.

adjoining springs, *B*, *B*. The lever has a fulcrum at *C*, which is usually in the middle of the lever, and the ends of the springs are

suspended from the ends of the lever by straps or hangers *D*, *D*. The opposite ends of the springs are connected to the frame of the engine by similar straps *g*, *g*. When one of the springs is compressed, one-half of the tension in it is transferred to the strap connected to the equalizing lever, by which it is carried to the end of the other spring, and through it, to the driving-wheel below it. In this way if one of the wheels encounters either a depression or an elevation on the track, the inequality of weight carried by the two wheels is at once equalized by the action of the springs and levers. Besides this advantage, it has another, which can be explained best by a very homely illustration. You have all noticed probably that a three-legged stool or tripod of any kind, will rest securely on a floor or other surface no matter how uneven it is, whereas a four-legged chair will be unsteady if the legs are supported by four points not in a plane. The same principle applies to a locomotive or other vehicle. You know a wagon rests on its two hind wheels, but the body in front is supported in the centre of the axle, so that the latter can oscillate more or less on that point. American locomotives are arranged very much in the same way. The back end is supported on the fulcrums of the equalizing levers, and the front end rests on the centre of the truck. It is thus practically supported on three points, and therefore it can adjust itself perfectly to the vertical inequalities of the road-bed just as a three-legged stool would adjust itself to an uneven surface.

A similar arrangement of equalizers is used, with engines having six and eight driving-wheels. In such machines, especially when a two-wheeled truck is used, there is danger that at times the truck may not carry its proper proportion of weight. To meet this, Mr. Hudson, formerly the Superintendent of the Rogers

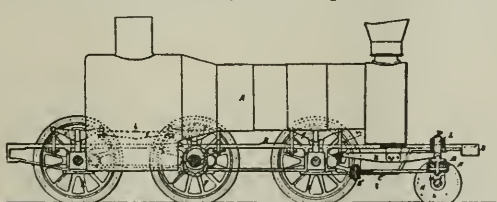


FIG. 22.

Locomotive Works, in Paterson, N. J., invented and patented an arrangement of equalizing levers, shown by *Fig. 22*. Such levers

were placed between the front driving-wheels and the truck. In his patent specifications, Mr. Hudson said: "If tracks could be made perfectly uniform and regular, and be maintained in that condition, my invention would be of little importance; but in practice, irregularities, more or less serious, occur at nearly every joint or junction of the ends of the rails, and at certain points in the track, as in passing switches and across tracks; and especially in passing over small obstacles or defects in the road, the inequality in the load, which is thrown upon the several wheels, becomes immense, unless, in addition to the use of springs, provision is made by introducing equalizing levers in some manner, to induce a unity of action between each pair of wheels and some other pair. The three pairs of drivers, *E*, *F* and *G*, have been connected together by equalizing levers; but I have never known the two pairs, *E*, *F*, to be connected together into one system, and the forward drivers *G*, to be connected to the truck-wheels, so as to form another and independent system, previous to my invention.

"My invention practically supports the forward portion of the structure at the point *k*, and the rear portion of the structure on the two points *i*, *i*, opposite the sides of the fire-box, thus making a triangle, on which the structure is carried, with a certainty of holding each wheel with sufficient force upon the track, and yielding easily and safely to every ordinary inequality."

This system has been applied to various types of engines, with Bissell trucks, and has much to do with their successful working. The use of equalizing levers has been a feature peculiar to American locomotives. European locomotive builders have aimed to secure a uniform distribution of weight on the wheels, by using long and flexible springs, but the merits of equalizing levers has been recognized by them of late years, and now they are applied to many locomotives both in England and on the continent. They serve the very important purpose of giving vertical adjustability to the wheels of a locomotive, which is very important on uneven roads. The truck, on the other hand, gives lateral flexibility to the system of wheels which carry the machine. It is these two features which were first adopted and have since been developed in this country, and which, for the service they had to perform, has given to American locomotives their superiority over those built in Europe.

The enormous increase in the weight of locomotives is not the least remarkable feature of their evolution. The "Rocket" weighed less than 10,000 pounds. At present, engines weighing over 100,000 pounds are not uncommon, and it is probable that the limit is not yet reached. But there are indications that another advance in the process of evolution must be taken, if the increase of the size and weight of locomotives continues. The gauge of railroads was, unfortunately, and to some extent by accident, made 4 feet 8½ inches. This was very well suited for the construction of engines of ten, twenty or even thirty tons weight, but when we get up to fifty tons, there is difficulty in getting room enough for a fire-box and boiler of sufficient capacity to supply steam for so large an engine. The standard distance between the flanges of the wheels for a 4 feet 8½ inches gauge road, is 4 feet 5⅜ inches. With the frames between the wheels and fire-box, the latter cannot exceed about 3 feet 8 inches in width. Therefore, in order to get a large fire-box, it must be made so long, that it becomes difficult to manage the fire. This has led a number of designers to devise plans which will permit the use of a wider fire-box than the limits named. Notably among these designs is that of Mr. Wotten of the Philadelphia and Reading Road. Probably most of you are familiar with his engines, so that no other description is needed than to say that he places the whole fire-box and grate above the wheels, which permits them to be extended laterally to any desired width. These locomotives, as most of you know, have been very effective in burning anthracite coal.

Precisely what form the locomotive of the future will take, it would be unwise to predict, but there are many evidences that the largest locomotives have nearly or quite reached the limits of size and capacity possible with the present plans of construction.

A good deal of speculation has been indulged in of late, in some of the technical papers, about the rate of speed which is attainable on our railroads.

For years past we have been told we would soon travel by rail at a speed of 100 miles an hour, if not faster; but the world has waited in vain for the fulfilment of this prophecy. To-day we are travelling faster than our fathers did twenty-five years ago, and it is a matter of wonder now, as it was then, when a speed of sixty miles an hour is maintained for any considerable time. There

must be some reason for this limitation of speed. Why is it that a locomotive can be made to run so fast, but refuses to be urged much faster? It is apparently in vain that the safety valves are screwed down, and the steam pressure increased or the wheels enlarged. Like the speed of a horse, when it reaches the traditional 2·40, it is exceeded only by the rare animals.

Persons who have only a slight acquaintance with the theory and the construction of locomotives, are apt to reason about this question somewhat as follows: It is not an uncommon thing, they say or think, for a thirty-ton engine with five foot wheels, to attain and maintain for a considerable distance a speed of fifty miles per hour and pull a train of, say, six cars. From these data, they will argue further, that if the wheels were doubled in size, all the other parts remaining the same and working the same; that is, the boiler making the same quantity of steam and the pistons an equal number of strokes, the speed would be doubled and the tractive or pulling force halved. In other words, the engine would run 100 miles an hour, and would pull three cars instead of six. Alas, for this theory! no one has ever run 100 miles an hour, or is likely to soon.

In the language of the immortal and genial Artemus Ward, one might ask, "Why is this thus?" There must be a fallacy somewhere. Our locomotive and its tender would weigh 100,000 pounds and each loaded car would weigh 50,000 pounds, so that the weight of the whole train would be 400,000 pounds. Now, be it observed, the load which a locomotive draws is its own weight *and* that of the cars; so that if the tractive or pulling power of our engine, when mounted on ten-foot wheels, is halved, the load it would pull would be only 200,000 pounds, or its own weight and two cars. This is on the assumption that the resistance of the train is the same at 100 miles per hour that it is at fifty. Unfortunately for the prophets again, there is a very great divergence of what may be called the line of this assumption and the actual facts. It must be admitted, though, that we do not know certainly what the resistance of trains is at high speeds, and, our knowledge of the resistance at any speed is still very imperfect and inaccurate. It seems to be uncertain, even, whether the law laid down in most of the text books that the resistance of the atmosphere increases as the square of the velocity, is true.

The article on "Gunnery," in the new *Encyclopædia Britannica*, contains the following statement:

"The resistance of the air to slow movements of, say, ten feet per second, seems to vary with the first power of the velocity. Above this the ratio increases, and, as in the case of the wind, is usually reckoned to vary with the square of the velocity; beyond this it increases still further, till at 1,200 feet per second the resistance is found to vary as the cube of the velocity. The ratio of increase after this point is passed is supposed to diminish again; but thoroughly satisfactory data for its determination do not exist."

To explain this in less scientific phraseology, the resistance of the atmosphere at a speed of 100 feet per second would be four times as great as it would be at fifty feet per second; or, in other words, if you double the speed, you increase the resistance four times, and at sixty miles an hour, the atmospheric resistance is about nine times as great as it is at twenty miles an hour. As indicated by the gunnery experiments, atmospheric resistance at higher speeds, probably increases in a still greater proportion. Although the resistance of the atmosphere is a comparatively small proportion of the resistance of railroad trains at slow speeds, it is a very important element at high speeds. The experiments in gunnery indicate, though, that at high speeds it is considerably greater than is ordinarily supposed.

There is no time, nor is this the place, to follow out these calculations further. It may be said though, that not only is the power required to pull a train at a high speed very much greater than at a slow one, but the steam which exerts this power must be generated in less time. That is, much more steam is required and must be produced in a shorter time than the smaller amount of steam was generated in before. Obviously this makes an immense boiler capacity essential, which adds to the dead weight to be hauled, and to the difficulty of pulling the train.

These and other considerations lead to the conclusion that we have very nearly reached the practical limit of speed of trains, unless some radical improvements shall be made in the motive-power employed. The fact, too, that twenty-five years ago locomotives ran very nearly if not quite as fast as they have since, notwithstanding the improvements which have been made in their

manufacture and construction, indicates that there are some physical laws which place a limit on the number of miles per hour that a locomotive can run. But even if there be such a limit, it does not diminish the wonderful results which have been wrought by this most fascinating of all machines. The secret of this fascination is not hard to explain. You can all remember the immense difference there was in your youthful minds, between a watch which would *go*, and one which would not. Perhaps none of you are too old, and certainly none are too young, to take delight in a chip, which by virtue of a bit of muslin or paper is converted into a ship, or to be pleased with a miniature water-wheel or wind-mill. They all have the element of *go* to them. But no human invention or creation is this *go* manifested in so impressive a way as it is by a locomotive.

I may repeat here what De Pambour wrote, more than fifty years ago, in the introduction to his treatise on *Locomotive Engines*, in which he said:

"We have studied the subject with all the interest, and we might say, with all the enthusiasm it excited in us. In fact, what a subject for admiration is such a triumph of human intelligence! What an imposing sight is a locomotive engine, moving without effort, with a train of forty or fifty loaded carriages, each weighing more than 10,000 pounds! What are henceforth the heaviest loads, with machines able to move such enormous weights? What are distances, with motors which daily travel thirty miles in an hour and a half? The ground disappears, in a manner, under your eyes; trees, houses, hills, are carried away from you with the rapidity of an arrow; and when you happen to cross another train travelling with the same velocity, it seems in one and the same moment to dawn, to approach and to touch you; and scarcely have you seen it with dismay pass before your eyes, when already it is again become like a speck disappearing at the horizon."

In the introductory preface to his *Treatise on Railway Machinery*, Mr. Daniel Kinnear Clark says: "The locomotive, naturally, was my chief object of study; and to the investigation of that admirable machine, its construction, its working and its performance, my attention principally was directed. I may add that the peculiar union of beauties, mechanical and æsthetical, to be found in the locomotive—the association of compact, concentrated,

mechanical action with freedom and elegance of form, and with the most graceful of movements—made me conscious that there was not alone a theorum to investigate, or a problem to solve, but an object, besides, of enduring admiration," which is a feeling I am sure you will all share, the longer you study this wonderful machine.

The GREAT BRUSH DYNAMO.

A DESCRIPTION OF THE GREAT DYNAMO-ELECTRIC MACHINE BUILT BY THE BRUSH ELECTRIC COMPANY FOR THE COWLES ELECTRIC SMELTING AND ALUMINUM COMPANY WITH AN ACCOUNT OF TRIAL TESTS MADE OF THE MACHINE.

By Dr. Robt. H. Thurston, Director Sibley College, Cornell University.

[*Read at the Buffalo Meeting of the American Association for the Advancement of Science, August 19, 1886, and Revised for Publication in the* Journal *by the Author.*]

The process of reduction of aluminum and other metals, and production of alloys, invented by Messrs. Eugene H. and Alfred H. Cowles, and perfected with the assistance of Professor Mabery, of Cleveland, O., has attracted the attention of engineers, as well as of men of science, not only on account of the ingenuity, simplicity, and effectiveness of the process itself, but also, and probably quite as much, because of its bringing into use the voltaic arc and dynamo-electric machines of exceptional and enormous power.

The writer, on the occasion of a recent trip to the West, was, on his return journey, so fortunate as to be able to stop in Cleveland long enough to witness the operation of the process, and to be present at the first trial of the great dynamo recently completed by the Brush Electric Company for the Cowles Electric Smelting and Aluminum Company The occasion was so interesting, and the facts developed so striking and probably important, that it has been thought worth while to present a very brief account of them to the members of this section of the American Association for Advancement of Science.

The Cowles process, as will be remembered by those who

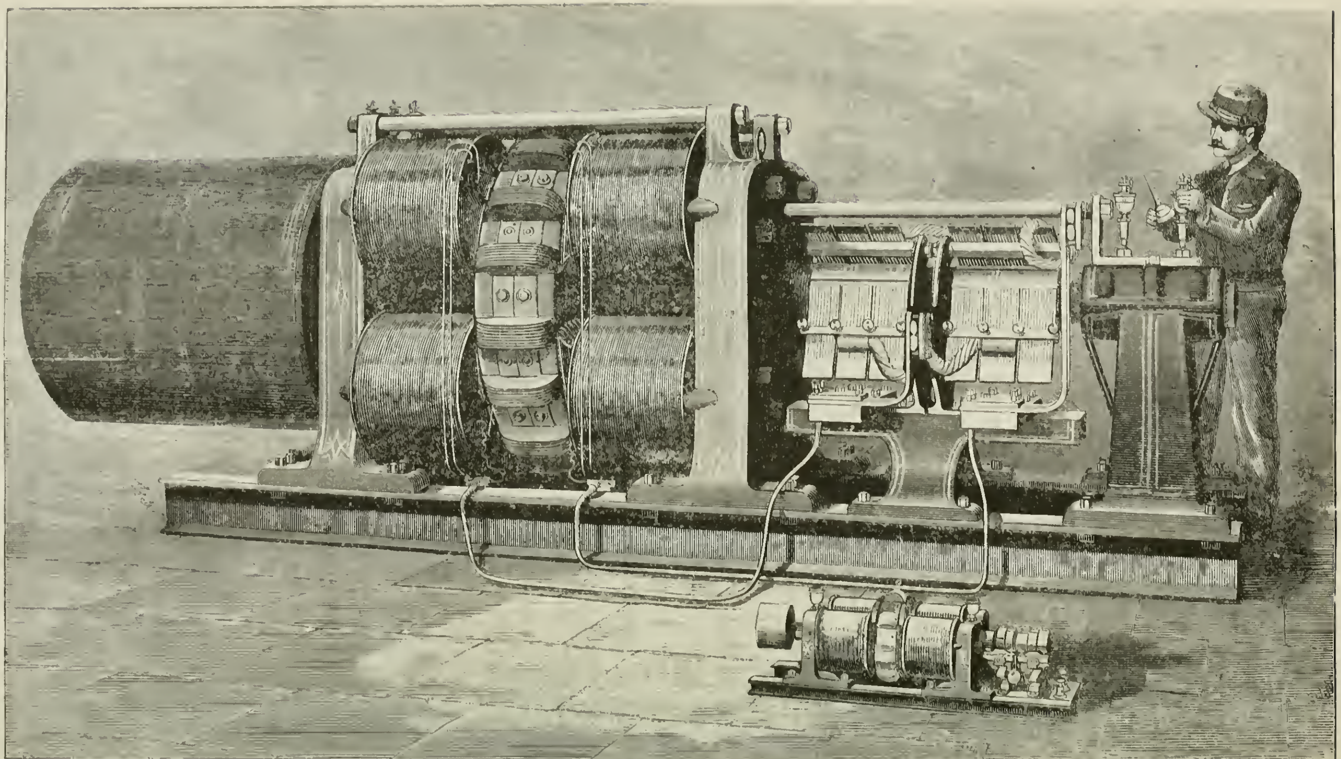
listened to the interesting account given the association at the Ann Arbor meeting of 1885, and published in the *American Journal of Science* for October of that year, or who have read the interesting paper of Mr. Eugene H. Cowles, read at the stated meeting of the FRANKLIN INSTITUTE, in January, 1886, and published in the JOURNAL for February, 1886, consists in the passage of a powerful current of electricity from a "dynamo" through a mass of ore mixed with carbon and other material forming the "charge," until the action of the heat, and possibly of the electrical force, causes a reduction of the ores and the formation of an alloy of the metals so reduced. The apparatus consists simply of a powerful dynamo-electrical machine, connected with a pair of carbon electrodes of correspondingly exceptional size, these electrodes being enclosed in a furnace of brickwork, lined with the most refractory available material. The Cowles Company have several dynamos, all of large size, but it is the intention of the writer to describe but one, the latest built and the largest. The next smaller, which was until recently considered a very powerful machine, weighs about two tons and a-half, is driven at 900 revolutions per minute, and produces a current of 1,575 ampères, with an E. M. F. of forty-five volts. These machines are "shunt-wound" and very nicely proportioned under the direction of the inventor, Mr. Charles F. Brush, whose interest in the work induced him to give to this construction his personal attention. The largest machine, recently completed, and under test at the time of the visit of the writer to the works, weighs 21,900 pounds, (9,934 kgs.) a so-called 42-inch (1060·6 mm.) machine, the armature having that diameter. The armature contains 1,600 pounds (725·7 kgs.) of iron; it carries 825 pounds (378 kgs.) of copper wire, while the field magnets are wound with about six times that weight, 5,424 pounds (2641·8 kgs).

The armature of this great dynamo consists of sixteen bobbins, each carrying twenty-one turns of best copper wire, two strands lying side by side, the wire being 0·35 inch in diameter (8·89 mm). These sixteen bobbins are operated in multiple arc, thus giving thirty-two strands of copper wire of the diameter above stated, and about sixty-five feet (19·8 m.) long. Sixteen copper bars carry the current from the bobbins to the commutator, each bar being one inch by one-half inch (25·4 mm. by 12·7 mm.) in section. The two commutators are coupled in multiple arc.

The field magnets are eight in number, and consist of a cylindrical cast iron core, 11 inches (279·4 mm.) in diameter, by 16 inches (406·4 mm.) in length, and wound with thirty layers of one hundred and two turns, each, of copper wire, 0·134 inch (3·404 mm.) in diameter; all the eight wires are coupled in multiple arc as in a shuntfield. Thus combined they have a resistance of about one ohm, total, cold. The pole pieces are of peculiar form, and fitted carefully to the field.

The driving shaft, carrying the armature, is 13 feet (3·962 m.) long, and 5½ inches (139·7 mm.) in diameter in the main bearing; it is made of open hearth steel, furnished by the Otis Company. The machine is driven by means of a 44-inch (1117·6 mm.) double belt, turning a 40-inch (1,016 mm.) pulley on the armature shaft. The machine occupies a space on the floor about 15 feet (4·572 m.) long, and 4 feet (1·219 m.) wide, and stands about 5 feet (1·52 m.) high.

This dynamo was calculated to furnish a current of 3,200 ampères, with an electro-motive force of eighty volts, with a normal maximum current in the field of eighty ampères; the speed of rotation not to exceed 600 revolutions per minute. Its actual speed was a little above 400 when doing the full amount of work demanded. The maximum field is thus obtained with but about two and one-half per cent. of the normal current (3,200 ampères), and falling to one per cent. when less E. M. F. is needed. When in operation, the writer found no observable heating in any part of the machine, and the bearings ran perfectly free from heating or cutting. The efficiency of the machine must be very great, as, after its longest run of two hours, the armature was cool enough to handle with perfect comfort. The writer could bear his hand on every accessible part of the machine, which included all parts liable to any serious heating. The belt was new and stiff, and occasionally slipped as the limit of the power of the machine was approached; but that was a fault which a little work would cure, by making the belt flexible and giving it a better bearing on its pulleys. Had the engine driving it been of sufficient power, it was evident much more work could have been done than was actually performed on the trial. It was judged that it might have been driven up to 300,000 watts with safety. The conductors provided, and the resistance coil used in measuring the power



The Great Brush Dynamo.

developed, were, however, about at the limit of their endurance. As it was, the former heating until they were blue, and the latter requiring constant watching and cooling by application of water. The maximum reached was 249,000 watts, or 334 electrical horse-power, the engine probably developing not far from 400 indicated horse-power. No indicators had been fitted, and it was impossible to measure this factor. The limit of its power was reached, however, and the power of the dynamo could not be tested to its maximum The speed intended was, for the dynamo, 430 revolutions, but at eighty volts it could not be driven by the engine up to that speed.

The dynamo was built, complete, in all its details, from the specifications of Mr. Brush, and without preliminary experiment, and, when tested, was found to require no alterations of any kind, and came fully up to the requirements of the specifications and contract. Its capacity is very much greater than that of any machine yet built in the United States, or in the world. Its successful construction is considered by its designer to indicate that it is possible to design a machine of any desired size and power, with perfect confidence that it will come fully up to the calculated performance. No limit is to be seen, as yet, to the size and power of the machines, if properly designed. Their construction is a matter of definite calculation, and is to-day independent of direct experiment. The fact that a dynamo may be precisely designed and proportioned for any kind and amount of work that may be demanded, for any purpose whatever, without limit, so far as can be to-day perceived, is one of the most interesting and important revelations of recent work in this field. The fact, also plainly shown by the experience of the Cowles Company, in the use of these enormous machines, that the larger the machine, the higher the duty of the plant, is no less interesting and important. The economy secured in the production of their aluminum and other alloys, by the increased size of the later dynamos put in operation, is so great as to be a very valuable factor in the operation of the business, each new and larger machine very considerably reducing the price at which the metals can be put on the market.

EXPERIMENTS WITH 42-INCH BRUSH MACHINE. JUNE 25, 1886.

Revolutions per Minute.	E. M. F. Volts in Ext. Circt.	Ampères in Ext. Circt.	Ampères in Field Shunt.	Watts in External Circuit.
428	78	1,000	33¼	78,000
424	68	2,000	30½	136,000
423	56	2,500	27½	140,000
420	66	2,600	37½	171,600
418	72	2,640	46½	190,080
410	76	2,700	58	205,200
420	94	2,040	89	191,760
412	88	2,450	85	215,600
410	86	2,700	83	232,200
410	85	2,800	82	238,000
405	83	3,200	80	249,000
423	56	2,700	29	151,200
423	54	3,150	35	170,100
423	62	3,400	45	210,800
423	66	3,400	50	224,400
423	68	3,400	52	231,200
423	52	3,000	33	156,000
421	46	2,950	28	135,700
421	36	2,620	21½	94,320
421	32	2,500	19	80,000
421	26	2,300	16	59,800
421	22	2,100	15	46,200
421	19	1,850	13	35,150
431	100	0,000	76	
431	105	0,000	100	

The tabulated statement shown, herewith, presents the figures obtained at the trial of the ten-ton dynamo above described, and will repay careful study, as they exhibit the effect of variation of speed, of variation of current in the fieldshunt, and of electro-motive force, in the production of energy in the external circuit. The highest power attained on this occasion was, as shown in line 11 of the table, 249,000 watts, the speed of revolution being 405 (twenty-five turns below the regular speed), the electro-motive force being eighty-three volts (three above the standard), and the current measuring 3,200 ampères. The electro-motive force in the shunt coils was eighty volts. The heaviest current measured 3,400 ampères, the electro-motive force being sixty-eight in the main current and fifty-two in the shunt, the current energy measuring 231,000 watts at the terminals. At the standard speed of rotation, the circuit being broken, the measured electro-motive force was 100 volts.

This remarkable and powerful machine was driven, at the time

of the visit of the writer to the works, by a Corliss engine through a heavy counter-shaft, the engine belt being carried over the belt from the jack-shaft pulley to the machine. This arrangement is an unusual, but perfectly practicable one, and, in this case, worked admirably. It was occasionally necessary to readjust the position of the dynamo, as the belt, which was new and stiff and smooth, stretched more on one side than on the other; but this stretching will soon cease, probably has ceased, and, as the belt becomes more flexible and more perfectly fitted to its pulleys, and as it takes its maximum stretch, it is evident that it will work with perfect accuracy and will be competent to transmit any load that the dynamo can be expected to throw upon it.

The current from the machine to the furnace was conveyed by ropes of fine copper wire, or by conductors made up of several heavy wires. At the furnace, they were connected to the terminals, which latter were of bar copper, apparently about two and one-fourth inches in diameter, armed with four carbons each, the latter of about the same diameter and four feet long. Between these was arranged the conducting material which furnished the incandescent bed in which the operation of reduction was carried on. This process is not, as is very often assumed, by professionals as well as non-professionals, an application of the voltaic arc to the production of high temperatures. Such an application was made by Sir William Siemens and by other experimenters from the time of the discovery of the intense heat of the arc; but it is, in the Cowles process, an application of the incandescence, as distinguished from the arc, system. A connection is established between the carbon terminals, by means of a mass of carbon and other material, which mass is carefully kept continuous and incandescent throughout the whole operation. This is essential both to the success, actual and economical, of the process, and as distinguishing it from the older and wasteful systems of melting. By this system, the intense, the immeasurable heat of the arc is tempered and diffused throughout a large volume of incandescent material, and becomes adjustable and capable of regulation with comparative ease and exactness. Such control is thus secured as to make it convenient and economical in application to the reduction of ores and the melting of alloys and metals. Actual contact carries, everywhere, probably a very large proportion of the current, and the heat is

distributed among numberless little particles of highly heated carbon, which lend each its share to the numberless particles of the compounds to be reduced.

It is probably only by some such application of the electric heat that corundum can be made to surrender its aluminum to form an alloy with copper. It has been stated recently, in the discussion of this process, as described by Dr. Mehner, before the Association for the Advancement of Science in the kingdom of Prussia, at the Berlin meeting of the present year, that this reduction had been accomplished in a furnace heated in the ordinary manner; but it would seem that this must be a mistake; since alumina is one of the most refractory substances known in nature; it is said to be even more so than the materials of our furnaces and of our crucibles. The Messrs. Cowles have subjected it to the highest temperatures that a Dixon crucible would bear, without being able to reduce it or to melt it, in the presence of carbon and copper. Further, it would be probably impossible to successfully maintain a reducing flame, if that were attempted, or to avoid the reoxidization of the metal were its reduction primarily possible. The reducing temperature of the compound is above the temperature of volatilization, also, of the pure metal, and this would make it improbable that its reduction in this way should be successfully performed, far less with commercial success. The volatilized metal would rapidly escape from the Siemens furnace or from any other familiar form of furnace, while no other process than that above described would be capable of forming the volatilized metal in a closed furnace. In the Cowles furnace it is practicable to reduce alumina either with or without the presence of copper or other alloying metal, and one of the first intimations of the production of the working temperatures in that furnace is the appearance of fumes, indicating some volatilization to be produced. As ordinarily conducted, this is not important in amount. Alloys of aluminum have been made in this furnace with nearly all familiar metals, a proof that copper, at least, is not essential to secure the reduction. So far as the writer has been informed, this is the only process by which reduction of this metal with carbon alone can be accomplished. The production of the metal commercially, in this manner, is expected to soon become an accomplished fact. The manufacture of the aluminum alloys has

now for some time been successfully carried on, the cost of the aluminum in the alloy having been reduced to a small fraction of the price for which the metal is sold as made by the older methods. The Messrs. Cowles and Professor Mabery have opened a new and broad field of experiment, and no one can surmise, even, what may come of the infinite range of possibilities so presented.

The COMPOSITION of CERTAIN PRODUCTS from the COWLES ELECTRICAL FURNACE.

By Prof. C. F. Mabery.

[*Read at the Buffalo Meeting of the American Association for the Advancement of Science, August, 1886, and revised for publication in the* Journal, *by the Author.*]

At the meeting of this association last year at Ann Arbor, a paper was presented by the Messrs. Cowles and myself, which gave a description of the electrical furnace and of the products which had then been obtained from it. During the past year, several improvements have been introduced into the construction of the furnace which have increased its efficiency very considerably; and, although, as compared with results that will probably be reached in the application of electricity to smelting purposes, the present development of the process may in the future seem very crude, it has already reached the stage when by actual trials, extending over considerable periods of time, its commercial success can be satisfactorily demonstrated. Those who listened to that paper, or who read it subsequently, will remember that the principle of the furnace is based upon the intense heat that may be produced by the resistance which is encountered when a powerful electric current is passed between electrodes through coarsely pulverized charcoal. In late experiments, it was found by A. H. Cowles that the efficiency of the charcoal could be largely increased, and the rather rapid formation of graphite prevented, to a certain extent, if the charcoal were coated with lime previous to using it. It was also found that the quantity of product formed was increased when the electrodes were allowed to enter the mixture of ore and carbon in an inclined position, at an angle of about 30° from the horizontal plane. A continuous reduction is more

easily effected when the electrodes are capable of being drawn apart so as to gradually expose fresh portions of ore to the action of the current. But perhaps the most important modification for the economy of the process is the adaptation of the furnace by the Messrs. Cowles for the reception of very powerful currents. It consists of a general enlargement of the furnace and the accessory apparatus, including electrodes, conductors and resistance-boxes with certain variations in the detail of its construction. Now the energy from 300 horse-power may be utilized instead of that from thirty horse-power, which was formerly employed. Inasmuch as the resources of the company have been fully occupied during the past year in the development of the commercial features of the process, it may seem that the scientific possibilities have not received due attention. While this criticism may be true in part, I think I shall be able to show that incidentally considerable material of some interest from a scientific standpoint has been collected. I have recently noticed certain statements of opinion concerning the furnace and the process that are not strictly accurate.

In the discussion that followed a paper read by Dr. Mehner, of Berlin, Dr. Martius was inclined to the belief that the metal aluminum was of no greater value for ornamental purposes than zinc, and that its alloys possessed no properties relating to corrosion, strength, etc., that were worthy of mention. These assertions can best be answered by referring to the actual properties of these metals which are established beyond doubt. But the opinion expressed by Dr. Werner Siemens, that so far as practical results are concerned, this electrical furnace is identical with that constructed by his brother, Sir William Siemens, is of more importance. The continuous working of an electrical furnace requires as nearly as possible a constant resistance between the electrodes. Assuming that a dynamo machine was carrying the energy from 300 horse-power and distributing it in an arc a few inches in length, and that suddenly the arc was broken by the introduction of fresh material, the effect upon the dynamo can be imagined. Dr. Siemens thought that the reduction of aluminum depended upon the presence of copper, and he expressed doubts as to whether reduction would result in its absence. Reference was made to the statement that aluminum bronze had been made in a crucible furnace by fusing together copper carbon and corundum. We have tried the

latter experiment at the highest temperature we could produce in a crucible furnace without the slightest reduction of aluminum. Nevertheless, it may be true that traces of aluminum can be introduced into copper by this method. The assertion of Dr Siemens that aluminum could not be reduced without copper is erroneous. We have repeatedly taken mixtures of metallic aluminum and carbon from the furnace in large quantities. The question by another chemist as to whether any analysis of the products had been made followed a remark by Dr. Martius that they did not need to be informed by Americans concerning aluminum or its alloys.

A product which has attracted considerable attention during the past year is obtained by reducing aluminum in presence of iron. A cast iron is formed containing sometimes as much as ten per cent. of aluminum, and this product is used to facilitate the working of crude iron and to introduce into the various grades a small percentage of aluminum. The slags resulting from this reduction are composed chiefly of calcic aluminate and cast iron. In the reduction of aluminum in the presence of copper, a yellow product is frequently taken from the furnace, which is composed of metallic aluminum to the extent of one-half or three-fourths, the balance being silicon and copper. With a small percentage of calcium it is also formed in the absence of copper and then contains a higher percentage of aluminum and often contains nitrogen. It has a resinous lustre and decomposes water at 100° C. The aluminum slags are composed of reduced metal, calcic aluminate and fused oxide, and since they have always proved to contain about one per cent. of carbon, which is liberated in the gaseous form by hydrochloric acid even in the absence of iron, a carbide of aluminum may also be present. A remarkable effect was observed in a bar of ten per cent. bronze which had been heated for the purpose of forging. It was allowed to become too hot and when struck the entire bar assumed a crystalline condition. Some of the individual crystals were nearly perfect in form, resembling certain forms of the isometric system. A striking analogy between them and certain forms of meteorites, has recently been observed by Mr. O.W. Huntington, of Howard College. In the reduction of silicon, the formation of a greenish-yellow substance is frequently observed, and it has proved by analysis to be a new oxide of silicon—$Si\,O$. By fusion with

fluxes it is converted into the dioxide, and hydrofluoric acid acts upon it the same as upon the dioxide.

The ingot of metallic aluminum here shown contains less silicon and iron than the average commercial metal, although no special care was taken to obtain a pure product. It was made by methods which are controlled by patents held by the company, and experiments are in progress which it is expected will lead to results that will cheapen very materially the cost of its production.

CARBOHYDRATE AND FATTY FOODS.

By N. A. Randolph, M. D., Philadelphia.

[*A Lecture delivered before the* Franklin Institute, *December 14, 1885.*]

Under the general heading of Fats is recognized a certain group of bodies composed of carbon, hydrogen and oxygen, which are capable of saponification and of emulsification, and which are insoluble in water. The true or neutral fats belong to one of three groups; stearine, palmitine and oleine; margarine being usually accounted a combination of the first and third. Chemically, each of these bodies is analogous in composition to any of the neutral salts. In the fats, however, the acid radical is represented by a fatty acid, and the base by glycerin. Thus, stearine may be regarded as the union of stearic acid with glycerin, and palmitine and oleine as respectively a palmitate and an oleate of glycerin. The fatty acid is, however, by far the preponderant portion of the molecule, the glycerin never exceeding from eight to ten per cent. of the substance. The fats named have been mentioned in the order of their solidity at ordinary temperatures, stearine being hard and oleine entirely fluid under usual conditions, while palmitine occupies an intermediate position in regard to density. As foods, these bodies are of extreme importance, though their full value has not been appreciated until a comparatively recent period, because, when taken to the exclusion of other foods, continued nutrition becomes impossible.

We eat fat in a nearly pure state in lard, in oils and in butter. It exists in varying amount in every organic food. Thus we find in

Meats, five to ten per cent.
Eggs, twelve per cent.
Milk, three to four per cent.
Butter, eighty to ninety per cent.
Cheese, from eight to thirty per cent.
Almonds, and nuts in general, fifty-three to sixty-six per cent.
And in all vegetables, from traces to two and three per cent

Fat is an integral constituent of the higher animals, being entirely absent only in the lowest. It is found not simply in the great reservoirs of the subcutaneous connective tissue, in the omentum, and around the kidneys, but also, finely divided and invisible to the naked eye, in every organ and fluid of the body. Its subdivision is so minute, and its distribution so wide, that especially for muscular tissue it has been well described as being "amalgamated" with the tissue. The chemical composition of fats of different animals is comparatively constant. The mean of eight analyses, including the fat of the ox, sheep, pig, dog, man, cat, horse and butter, revealed an average constitution of $C_{76 \cdot 5}H_{11 \cdot 9}O_{11 \cdot 6}$, while in the separate analyses these figures differ scarcely one per cent. from one another. Curiously enough, however, the difference in the chemical constitution of the fats of different animals gives to these animals their characteristic odors.

Just as in the body as a whole we find an inverse ratio between its fatty and watery constituents, so in the fatty tissues proper we find a similar relationship. This is strictly correlated with the histogenesis of adipose tissue—*i. e.*, the fat globules are produced in the connective-tissue corpuscle at the expense of the contained watery protoplasm. From figures gained by actual analyses, it may be stated that in the average healthy adult, the fat equals eighteen per cent. of the entire body-weight, or forty-four per cent. of the weight of the dried body.

The extremes in the proportion of fat in the body coincident, apparently, with health, have been most carefully studied in the domestic animals. Thus, in sheep of different degrees of fatness, the following percentage relations in their proximate composition have been found to obtain :

	Per cent. Water.	Per cent. Albumen	Per cent. Fat.	Per cent. Ash.
Thin sheep, ...	57·3	18·4	18·7	3·16
Moderately fat sheep, . . .	50·2	14·0	23·5	3·17
Fat sheep, ...	43·4	12·2	35·6	2·81
Very fat sheep, ...	35·2	10·9	45·8	2·90

In order to appreciate the importance of fats in the economy, we must turn to the phenomena occurring as a result of abstinence from food. In this condition, there is constant disintegration of albumen and fat, the destruction of the latter being twice as great as that of the former. To prevent further loss of fat, either albumen, fat or carbohydrates must be given.

That by its metabolic activity the body can make fat out of other than fatty substances is fully established. A cow subsisting on hay alone accumulates and secretes many times as much fat as she takes in her food. A woman in lactation also secretes much more fat than is ingested. In the process of fattening pigs it has been shown by direct analysis at the end of the experiment that for every 100 parts of fat in the food consumed, 472 parts of fat are stored up in the body. Perhaps the most striking illustration of metabolic fat production is found in the experiments conducted by Hoffmann on a maggot's eggs. The fat percentage in a given weight of these eggs was determined, and a corresponding quantity were allowed to develop in defibrinated blood. When the maggots became mature, it was found that the fat in the eggs from which they were developed, plus the fat in their food, constituted a little less than one-tenth of the fat extracted from their bodies. Here the fat production could be attributed only to separation of albuminoids into other nitrogenous matters and fats.

Pathologically, we frequently see a retrograde metamorphosis of albumen, which constitutes fatty degeneration. Somewhat similar in nature is the post-mortem production of adipocere, in which the proteids of the body have been broken up, possibly by bacterial agency, with the production of the higher fatty acids. The bodies last named unite with earthy and ammoniacal bases to form an insoluble soap, which replaces and assumes the form of the destroyed tissues. As a result of poisoning, especially by

phosphorus, there is also noted a similar production of fat resulting from the decomposition of albumen.

Admitting, now, that fat may be made in the body from albumens, it becomes interesting to note the amount of albumen requisite in the otherwise starving animal to prevent for a time any loss of fat. This quantity is large, and is in inverse ratio to the amount of fat already in the body. In very meagre individuals, it would be impossible to prevent loss of fat under these circumstances, as the requisite amount of albumen would be more than could be digested. By the addition, however, of a small quantity of fat to the albumen, a much smaller quantity of the latter is sufficient to prevent decrease either of the albuminous or of the fatty tissues. As we shall see in studying the history of the proteids of the economy, the most rapid destruction of these compounds takes place not in the formed tissues, as was formerly supposed, but in the circulating fluids. Close chemical studies have shown that when fats are present in company with the circulating albumens they greatly retard the destruction of the latter. In other words, the functionally active cell in any part of the body is bathed in a fluid containing both proteid matter and fat. Only a portion of the force of that active cell is derived from the disintegration of the albuminoid, the remainder being gained from the destruction of the fat. It is especially under muscular activity that the destruction of the fats is most marked, and for this reason they form a most important element in the dietary of the laboring classes. This power of fats to prevent the destruction of the albumens of the body is illustrated by the fact that a moderately fat individual will resist starvation for a longer period than will one of equal muscularity but greater specific gravity. Nevertheless, fat alone is a very insufficient food. It retards the destruction of the albumens, and therefore prolongs, though it cannot sustain life. Thus, Magendie fed two dogs, one on butter, the other on lard, without other food. The first lived sixty-eight days, the other fifty-six. The post-mortem examination showed an accumulation of subcutaneous fat, but general atrophy of the organs. Rats, also, which, in the absence of all food, starve in from three to nine days, will live upon fat for from twenty-six to twenty-nine days.

Under normal conditions, the fats ingested are absorbed with remarkable completeness and in surprising quantity. Thus, in a

dog of nearly eighty pounds weight, to which was given in one day eleven ounces of fat in conjunction with other food, a little less than a drachm of fat could be obtained from the fæces. The maximum limit of fat absorption is not yet established, but it is doubtful whether the amount last mentioned could be absorbed during many successive days. On the contrary, it is highly probable that a degree of saturation of the circulating fluids would be obtained beyond which further absorption would not occur. Experiments instituted by the writer (aided by Dr. Roussel) upon twenty healthy individuals (both infants and adults) with a view of determining the question of the cutaneous absorption of fats, gave the following results:

At the beginning of the experiments, the fæces were, in each case, found to be practically free from fat. After continued inunction of cod liver oil, applied twice daily for a period of two weeks, there was found not only a gain in weight of the individuals (with whom the general dietary had been unchanged), but a notable quantity of fat present in the alvine dejections. This could only be attributed to a kind of saturation of the fluids of the body, which, as a result, prevented further absorption of fat from the intestinal surface, the fat found in the dejections corresponding, therefore, to unabsorbed fat taken in the food. This supposition is strengthened by the observations of Berthé, who showed that pure cod liver oil, given internally, could be taken for a longer time without appearing in the fæces, than could an equal amount of butter or any of the other animal and vegetable fats.

When we remember that the absorption of ingested fats is, in all probability, a result of the purely vital activity of the protoplasm of the intestinal epithelium, it is not difficult to understand the rejection of a needless aliment by this absorbent surface. It is a manifestation of protoplasmic selective power analogous to that exhibited by two dissimilar plants drawing from the same soil each its distinct and special pabulum. Such intestinal selection is illustrated by the behavior of petrolatum (cosmoline, vaseline) in the digestive tract. This substance, while non-saponifiable and chemically distinct from the fats, presents many points of physical resemblance. Prompted by this resemblance, the query arose in my mind, a few months ago, as to the possible absorption of this soft hydrocarbon by the human digestive tract and its subsequent oxi-

dation in the tissues; in other words, whether it could or could not be utilized as a food. On each of eight days I swallowed half an ounce of commercial vaseline, and caused my laboratory assistant to do the same. Digestion was not disturbed in either case, and no noticeable effects ensued. Later, to each of two healthy adults there was given, in the course of forty-eight hours, one ounce of vaseline. Their fæces for three days from the beginning of this experiment were collected, dried, and extracted with petroleum ether. From the extract the vaseline ingested was entirely recovered—evidence of its complete rejection by the intestinal surface. In further experiments upon other individuals, I have found that petrolatum, administered internally, is often sufficient to check rather severe diarrhœas of irritation, apparently acting simply as a mechanical lubricant, which exerts its soothing effect upon the entire irritated surface. It is a curious fact that petrolatum is also efficient in relieving constipation, its action being, of course, that of an unabsorbable diluent of the intestinal contents. The amount requisite to produce the desired result is in this case, however, too large to render the method one of any general usefulness.

In abnormal conditions, such as mechanically obstructed or otherwise impaired biliary or pancreatic secretion, or from diminished activity (from any cause) of the intestinal epithelium, fatty stools are noted. In health, however, fat is found in but minimal amounts in the excreta, although other unabsorbed food elements —bits of muscle fibre, starch, etc.—are readily found. Curiously enough, the presence in the intestinal contents of bran, woody fibre, and the like, materials which impede the proper digestion and absorption of the proteid foods, have little or no effect upon the practically complete absorption of fats. Rubner has shown that the human intestine can absorb large quantities of fat—much larger, indeed, than in the case of the dog just cited; but the length of time during which such absorption could be continued was not determined. In comparison with ham fat, he found butter to be by far the more readily absorbed. Previous accurate observations, already cited, have shown that cod liver oil is absorbed with greater ease and to a greater degree than any of the other fats. The vegetable oils, on the other hand, are the least readily absorbed.

In every sound nutritive schema we find that the fats occupy a

prominent position. It is very significant, in this connection, to note that in the first food of the mammal the fats and albumens are present in practically equal parts. It, of course, goes without saying that a fat which is not entirely fluid at the temperature of the viscera is with difficulty susceptible of emulsification and absorption, and may prove an irritant to weak digestive organs. Although the fats of high melting point contain olein, which is fluid at ordinary temperatures, there is also present sufficient stearin to render a higher temperature requisite for melting the mixture. Thus, the melting point for the fat of mutton is from 41° to 52° C.; for beef, 41° to 50° C.; for pork fat, 42° to 48° C.; whereas the fat of the horse, rabbit and goose is fluid at from 24° to 30° C. These facts suggest the cause of the widespread preference for fats which, in popular phrase, "melt in the mouth."

When digestion and absorption are imperfect, fats may become irritants by undergoing a decomposition which exceeds physiological bounds, with the production of volatile and irritant fatty acids possessing characteristic rancid odors. Somewhat similar decompositions occur at the temperature requisite for frying. This we must regard as one factor in the frequent cases of indigestion of fried foods; and a further reason that the fats, especially when cooked with other foods, are frequently found to be unwholesome is that, in the process of cooking, they so surround and saturate the tissues of the substance with which they are combined that it is rendered nearly inaccessible to the action of the saliva and gastric juice, and at times digestion is in so far delayed that the fried substance does not become entirely freed from this more or less impervious coating of fat until subjected to the action of the pancreatic juice.

Under ordinary circumstances, the fatty acids of the neutral fats are not taken into the economy as such, but in combination with a small amount of glycerin. The fatty acids, however, alone are fully capable of replacing the neutral fats as a food. When administered to a dog in the form of soaps, in conjunction with meat from which all fat had been removed, Munk found that the animal gained in weight in precisely the same way that it would have done had the acid been given in its more usual combination. No nutritive value, strictly speaking, has as yet been determined for the glycerin found in fats, but it is believed that, in the form of

glycero-phosphoric acid, it carries phosphoric acid to the tissues where the latter acid is needed. It is quite well established that the lecithins, which are important constituents of brain tissue, are direct derivatives of glycero-phosphoric acid.

A Carbohydrate is a compound of carbon, hydrogen and oxygen, in which the elements last named are in the proportion requisite for the formation of water. The carbohydrates of the economy and of its foods may be grouped in four classes.

The first includes the glucoses, which possess the formula $C_6H_{12}O_6$. The word glucose may be used as synonymous with grape sugar, dextrose, starch sugar and liver sugar. Glucose is constantly found, in minute quantity, in blood, chyle and muscle. An excess above the small maximum normal to these tissues is immediately rejected and excreted; thus, a solution of glucose injected into a vein at once makes its appearance in the urine, and the glycosuria of diabetes mellitus is attributed to a nervous disturbance of the hepatic function, which permits the entrance into the circulating fluids of a greater amount of this substance than is normal.

In the vegetable kingdom glucose is widespread, being found in the sweet juices of ripe fruits and in the honey of flowers. It is physiologically produced in germinating seeds by the action of the amylolytic ferment therein contained. It is crystallizable, combines feebly with bases, salts, acids and alcohols, and has a reducing action on many metallic oxides. By fermentation with yeast it separates into alcohol and carbonic acid, and in the presence of decomposing albumen it splits into two molecules of lactic acid, which, in alkaline solutions under the same conditions, may be yet further decomposed into butyric and carbonic acids and hydrogen. To this group belong, also, galactose, produced by the action of diluted acid upon sugar of milk, and levulose, an isomeric body, which, however, rotates the ray of polarized light to the left. It is a by-product in the intestinal digestion of starches.

The second division of the carbohydrates contains those of the formula $C_{12}H_{22}O_{11}$, commonly called the saccharoses. They may be regarded as anhydrides of the double glucose molecule. Their physiological type is lactose, or milk sugar, and their type, from a dietetic point of view, is cane or beet sugar. Lactose is capable

of change by direct fermentation into lactic acid, and indirectly by yeast into alcohol, as in the production of koumiss. Cane sugar is, in some degree at least, transformed into glucose before it is absorbed.

The third group includes the carbohydrates of the formula $C_6H_{10}O_5$—*i. e.*, starches, dextrin, cellulose, gums and glycogen. One of the most striking differences between the green plants and all animals lies in the power possessed by the former of manufacturing starch from inorganic substances. The chlorophyl of the green plant, when stimulated by sunlight, can induce the union of six molecules of atmospheric carbon dinoxide with five molecules of water, with the resultant production of one molecule of starch and the liberation of oxygen. No such synthetic power is possessed by any animal, and for the manufacture of a carbohydrate in the animal there is requisite, therefore, either a preexisting carbohydrate or the destruction of an albuminoid. Starch, in its raw state, is entirely insoluble in water. When boiled, the granulose, which constitutes the major portion of the starch grain, and which is contained within an enveloping membrane of cellulose, becomes swollen and ruptures the membrane, with the production of the common starch jelly or paste. Such mechanical hydration of the starch granule is very essential to its digestibility, as the cellulose envelope is but little affected by the saliva. The pancreatic juice, however, is fairly useful in dissolving even raw starch. Starch frequently causes indigestion, when eaten in large quantities, from the following causes:

(1.) Glucose may be formed more quickly than it can be absorbed, and, by its presence, retard the further digestion of the starch.

(2.) Starch, when long retained, is liable to fermentation, with the evolution of butyric acid, thus causing persistent diarrhœas, especially in early childhood.

Much diversity of opinion exists as to the digestion of starches in infancy. I have settled this point to my own satisfaction by the microscopic examination of the fæces of twenty-four starch-fed infants, aged from forty-five days to eighteen months.

The results of this study will be found in the following table.

No.	Age.	Food.	Starch Present.	Remarks.
1	45 days.	Condensed milk and cracker-dust.	None.	
2	2 mos.	"	Traces.	
3	2+ "	"	"	
4	3 "	"	"	Twice examined: no fat before inunction, about 10 per cent. after.
5	3 "	"	"	
6	3 "	"	About ¼ starch.	
7	3 "	"	Traces.	
8	4 "	Corn-starch and milk.	"	
9	4 "	Condensed milk and cracker-dust.	None.	Many broken cellulose envelopes.
10	4+ "	"	Traces.	Evidences of potato surreptitiously given.
11	5 "	"	About ½ starch.	
12	5+ "	"	None.	
13	5+ "	"	"	Many bacteria.
14	6+ "	"	"	10 per cent. fat; had had inunctions.
15	8+ "	Breast and cracker food.	Traces.	
16	10+ "	Condensed milk and cracker-dust.	More than normal.	Many bacteria; evidences of potato surreptitiously given.
17	13— "	"	20 to 30 per cent.	Some glucose present, and indications of dextrin; saliva was found to be inefficient.
18	14— "	"	Traces.	
19	14 "	"	"	
20	14 "	"	10 per cent starch.	Sick.
21	14+ "	"	None.	Except a few large cells containing starch from potato.
22	17— "	"	"	
23	17— "	"	Over ¾ starch.	Syphilitic; saliva was found to be inefficient
24	18 "	"	Traces.	Indications of dextrin.

It should be observed that the word "traces," applied to the presence of starch in the fæces, does not indicate inefficiency of starch digestion. Similar traces of starch are found in the fæces of nearly every healthy adult upon a mixed diet.

It may legitimately be deduced from this study that in *many* cases starch is well digested in early infancy, that the individual variations in this regard are too numerous to permit any sweeping statement, and that the physician may assure himself as to the peculiarities of the case in hand only by a direct examination of the dejecta.

If an infant cannot digest starch, it is self-evident that starch is worse than useless as an ingredient in its food. The converse of this does not obtain; the mere fact that a given infant can digest a certain quantity of a farinaceous material is in itself no proof that such material is a useful ingredient in the dietary of that infant. The ratios existing in human milk between carbohydrate, fat and proteid cannot with safety be greatly altered in an artificial food for early infant life.

Dextrin is prepared by superheating dry starch, and is also found as an intermediate product in the action of dilute acids, and of digestive juices upon starch. It is chemically isomeric with the starch, but presents certain physical differences from this body, being soluble in water, and also much more tenacious as a mucilage. Dextrin is probably absorbed to some degree unchanged from the digestive cavities, inasmuch as there is found in the blood of the portal vein during digestion a substance which gives characteristic reactions, and possesses its properties.

Cellulose is found inseparably associated with the formed tissues of the vegetable kingdom, being one of the chief constituents of the vegetable cell-wall. Its digestibility depends largely upon its age, and upon the extent to which it has been cooked. When young and tender, as in celery, asparagus, and salads, about one-half of its substance is digested, the remainder being of service in giving the proper bulk and consistence to the intestinal contents. This it does, however, at the expense of the complete absorption of the proteid food-stuffs.

The gums possess no permanent nutritive value. Many authors claim that they are entirely unaffected by the digestive processes, but later studies have shown that they are absorbed to the extent of from forty to fifty per cent.

Glycogen, besides being a normal constituent of the human economy, is found in many foods. It is always present in the normal liver in varying amounts, the maximum being obtained in the livers of cattle, where it forms from fourteen to seventeen per cent. of the entire liver substance. It is further found in muscle, in most embryonal tissues, and, according to Pavy, also in the spleen, pancreas, eggs, brain and blood. It is present in considerable amount in the large livers of oysters and other mollusks.

The fourth division contains but one member, viz., inosite. This is a sweetish sugar, isomeric with glucose, but entirely incapable of other fermentation than the sarcolactic. It is variously known as muscle-sugar, bean-sugar and phaseomannite. It exists normally in muscle, where it is decomposed by each muscular contraction, with the resultant production of saracolactic acid. It has also been found in lung, liver, spleen, kidney and brain of oxen. It exists normally in the human kidney and pathologically in the urine. It is found in all the leguminosæ, and also in grape-juice.

We have seen that there are present in the tissues of the body both fats and carbohydrates. The origin of the various carbohydrates is, in greater part at least, directly or indirectly from similar carbohydrates taken as food. Thus, for instance, the glycogen of the liver greatly diminishes in amount in the absence of carbohydrate food stuffs. This is not the case with the fats. Foods containing starch and sugar are well known to be fattening. The explanation of this would at first sight seem to be that fat is made out of these bodies by the metabolic activity of the tissues. This explanation, however, is not correct. The true cause of the increase of body fat upon a mixed diet containing an excess of carbohydrates lies simply in the fact that these bodies become oxidized in the place of the albumens, thereby sparing the latter to fulfil their nutritive functions, and finally to produce fat. The ingested fats aid in the production of fat in the economy, both in this indirect manner and also directly replacing fats already oxidized and disintegrated.

It will be seen from this brief statement that in a mixed diet containing inorganic foods, proteids, fats and carbohydrates, the members of the last two groups are capable of replacing one another to a large extent, for their functions are practically the same, *i. e.*, each sacrifices itself in the oxidation flame of life for the sake of the more valuable proteid tissues and fluids. This is more marked in the case of the carbohydrates, which are able almost entirely to replace the fats in a dietary. Under these circumstances, however, there is found to be a considerable tax upon the metabolic activity of the tissues in manufacturing the fats. In like manner, animals fed exclusively on meat will manufacture from their own tissues the needed carbohydrates in much greater quantity than that in which they exist in the food taken. But here again comes a strain on tissue metabolism, and practically it is found that, other things being equal, it is best to have both the carbohydrates and fats present in the food.

Thus far we have considered similarity in the two groups of organic non-nitrogenous foods. There are, however, certain differences. Thus, a given weight of fat represents one and three-fourths times the nutritive value of the same weight of sugar or starch. Although both of these bodies are heat producers, the fats again have the advantage, and it is for this reason that they assume such

high nutritive importance in cold countries and are consumed by us to a much greater extent in winter than in summer.

The direct bearing which these facts have upon the subject of corpulence is evident. The man who is fat does not of necessity partake too freely of starch and sugar or of oils. He is simply a man who eats too much. His powers of digestion, absorption, and especially of assimilation, are usually far superior to those of his thin neighbor, who may, and often does, eat far more than his obese friend. The plump patient, therefore, must not console himself with his relative temperance in food. He stands perpetually self-convicted as a man who consumes more nutriment than is needed to repair his daily wear and tear. So active are the nutritive processes in his body that he can say with poor Byron, "Everything I eat turns to tallow and sticks to my ribs." He can, of course, reduce his fat by abstinence from carbohydrates and fats, but in so doing he not only violates his nature by turning carnivore, and seriously taxes his emunctories in eliminating an excess of nitrogenous waste, but he needlessly alienates too much tissue-force by the tax and strain of excessive metabolic activity. To permanently and harmlessly reduce his bulk it is necessary simply to very gradually reduce the daily total of his aggregate mixed diet. The popular belief that the ingestion of much fluid is fattening probably arises from observations of the use of fluids other than water.

Given the same degree of obedience on the part of a fat and of a thin patient, it is generally much easier to reduce the former than to fatten the latter. In the first case it is purely a question of abstemiousness. In the second, the simple administration of food in excess of the bodily needs, if unaided by a corresponding stimulation of the assimilating powers, is not infrequently worse than useless. Such a nutritive stimulus may be obtained by the conjoint use of enforced rest, passive exercise by massage and electricity, and a dietary gradually increasing in bulk and variety, the chief factor in which is milk.

For the details of this latter process, I would refer the reader to that gem of medical monographs, Mitchell's *Fat and Blood.*

COEFFICIENT OF EFFLUX FROM AN ORIFICE FURNISHED WITH A SHORT PIPE.

By J. P. Frizell, C. E.

It is well known that the application of a short pipe to a simple orifice in a reservoir results in a material increase of the discharge. Most writers on hydraulics treat this phenomenon as an ultimate fact of science to be determined only by experiment. It is, of course, sufficient for practical purposes, when this case occurs, to

be able to make use of the experimental coefficients of efflux. It is greatly conducive, however, to clearness of knowledge to be able to refer this fact to the well known principles of impact and momentum. Moreover, in hydraulic computations, the same phenomenon presents itself in many forms to which no experimental coefficient is applicable.

The writers* of the splendid article "Hydro-mechanics," in the new *Encyclopædia Britannica* give their view of the rationale of this phenomenon, and express the coefficient of efflux from a short pipe thus:

$$c = \frac{1}{\sqrt{1 + \left(\frac{1}{\mu} - 1\right)^2}}$$

μ being the coefficient of efflux from a simple orifice, c that from the short pipe. If μ be put $= 0{\cdot}615$, this gives $c = 0{\cdot}85$, which is an approximation to the truth, but too large.

My own reflections on the subject lead to a somewhat different formula, which I think it worth while to put in print.

* Professors A. G. Grunhill and W. C. Unwin.

Let v_1 be the velocity with which the water enters the pipe, *i. e.*, the velocity in the smallest section of the contracted vein at the entrance.

$v_2 =$ the velocity of discharge from the pipe.

$h =$ the static head acting on the orifice. This is sometimes measured to the upper edge of the orifice and sometimes to the centre. For this reason tabular coefficients of efflux differ. It must be understood in the same sense with reference to the entrance and exit of the pipe.

$\mu =$ the coefficient of efflux from a simple orifice of the form under consideration.

$\Phi =$ coefficient of velocity from the same. So that the discharge from a simple orifice, of area A, is $A \mu \sqrt{2 g h}$, and the velocity is $\Phi \sqrt{2 g h}$. It is well known that the velocity of issue from a simple orifice falls a little short of that due the static head; a fact which may ordinarily be neglected, but must be taken account of in computations relative to impact and living force.

The water enters the pipe with the velocity v_1 and issues with the velocity v_2. During the passage through the pipe, therefore, an amount of energy, represented by

$$\frac{v_1^2 - v_2^2}{2 g},$$

has disappeared. I say energy, although the idea of energy involves the weight of water discharged per second. But as this element does not vary during the computation, it is just as well to regard the energy as represented by the head.

A certain loss of energy occurs in the abrupt change of velocities from v_1 to v_2. According to well known principles, this is represented by

$$\frac{(v_1 - v_2)^2}{2 g}$$

This accounts for a part of the energy that has disappeared in passing the pipe, but not all of it. The remainder is represented by

$$\frac{v_1^2 - v_2^2 - (v_1 - v_2)^2}{2 g} = \frac{2 v_2 (v_1 - v_2)}{2 g}.$$

What has become of it? It has been expended in diminishing the atmospheric pressure, which opposes the flow of the water. In other words, the flow of the stream has been increased at the expense of its energy. The water enters the pipe with the velocity that would be imparted to it by the static head

$$h + \frac{2 v_2 (v_1 - v_2)}{2 g}; \text{—say } h + H.$$

but

$$\frac{v_1}{\Phi} = \frac{v_2}{\mu} \text{ or } v_1 = \frac{\Phi}{\mu} v_2$$

whence

$$H = 2 \left(\frac{\Phi}{\mu} - 1 \right) \frac{v_2^2}{2 g}.$$

The head required to impart the velocity v_1 is

$$\frac{1}{\Phi^2} \frac{v_1^2}{2 g} = \frac{1}{\Phi^2} \left(\frac{\Phi}{\mu} \right)^2 \frac{v_2^2}{2 g} = h + 2 \left(\frac{\Phi}{\mu} - 1 \right) \frac{v_2^2}{2 g}$$

whence

$$v_2^2 = \frac{2 g h}{\left(\frac{1}{\mu} \right)^2 - 2 \left(\frac{\Phi}{\mu} - 1 \right)} \quad \therefore$$

$$\frac{v_2}{\sqrt{2 g h}} = \text{coefficient of efflux} = \frac{1}{\sqrt{\frac{1}{\mu^2} - 2 \left(\frac{\Phi}{\mu} - 1 \right)}} = c.$$

The value of Φ is, according to Weisbach (*Mechanics*, etc., Coxe, p. 855), 0·975. μ varies slightly with the head. Weisbach takes 0·615 as the working value of μ. Substituting these values in the formula for c, we have $c = 0{\cdot}824$. Weisbach gives 0·815 as the mean experimental value of c, but the values found by different experimenters differ considerably.

Electrified Bubbles.—At the Royal College of Greenwich, soap bubbles were blown of a cylindrical form, and in a vertical position between two concentric platinum rings which served as electrodes. When the bubbles are left to themselves, they exhibit a series of colors in horizontal bands which gradually enlarge and descend; a black band soon appears toward the top and also extends downwards. Electric currents tend to transport the liquid to the negative pole, thus retarding the motion of the bands if the negative electrode is at the top, and accelerating it if the negative electrode is at the bottom.—*Cosmos, Sept. 7, 1885.*

REPORT OF THE COMMITTEE ON SCIENCE AND THE ARTS ON IVES'S PROCESS OF ISOCHROMATIC PHOTOGRAPHY.

HALL OF THE FRANKLIN INSTITUTE,
Philadelphia, November, 1885.

The Sub-Committee of the Committee on Science and the Arts, constituted by the FRANKLIN INSTITUTE, of the State of Pennsylvania, to whom was referred, for examination,

FRED E. IVES'S IMPROVEMENTS IN ISOCHROMATIC PHOTOGRAPHY,

Report: That they have carefully considered the process published by Mr. Ives in the *Philadelphia Photographer*, page 365, No. 192, December, 1879, under the title, "On Photographing Colors."

In this paper, attention is called to the fact that colors which, to the eye, seem light, will often photograph dark; while some colors looking dark, photograph light. He claimed at that time to have perfected a process of value in copying oil paintings, and also in making pictures of natural scenery, when a long exposure is possible; and he proceeds to describe the process as follows:

"I place the object to be photographed in a strong light if possible, and use a quick-working objective, directly in front of which is placed a lantern tank, having thin plate glass sides, nearly half an inch apart. Fill the tank with a solution of bichromate of potash, containing one part of bichromate to 1,000 parts of water; focus as usual. Then prepare a plate with 'Newton's emulsion' (I always manufacture it myself, and find it uniform and perfectly reliable) as follows:

"As soon as the emulsion is set, pour upon it a little acoholic solution of chlorophyl (formula below), and float it backwards and forwards for about thirty seconds, after which wash until smooth. Then flow with tea organifier (tea, one-half ounce; water, ten ounces), rinse and expose about two and one-half times as long as required with plain emulsion without tank of yellow.

"Develop with the sal-soda developer (I make this double the strength recommended by Mr. Newton, and dilute where over exposure is suspected). If the bichromate of potash solution is too intense, blue and green will photograph too dark. I have given

the proportions I find perfectly adapted to my tank, lens and chemicals.

"To prepare the chlorophyl, first extract everything soluble in water from myrtle or tea leaves, by treating with a number of changes of hot water; then dry the leaves, and the chlorophyl may be extracted at any time by treating about one ounce of leaves with four ounces of hot alcohol.

"Myrtle leaves yield the most chlorophyl, the solution of which should be a deep pure green color, and will remain good a long while, *if kept in the dark.* It spoils very soon if exposed to a strong light."

Mr. Ives submits to your committee photographs taken from highly-colored pictures, in comparison with photographs made from the same highly-colored pictures by the ordinary wet collodion process. He submits also a chromo of two men playing cards, this is highly colored with plenty of bright yellow and red in contrast with blue. This chromo has been photographed by Mr. F. Gutekunst of this city, using a colored glass before the lens, but not using the chlorophyl as recommended by Mr. Ives.

The result is unsatisfactory; yet, from the well-known skill of the operator, your committee is convinced that it represents the best result obtainable by the ordinary methods of photography, aided by the colored glass. The same chromo photographed by the Ives process, substantially as given in the *Philadelphia Photographer*, in December, 1879, is perfect in detail, and in the gradation of light and shade, as expressed by light or dark pigments, regardless of the actinic effect of the color used. Thus the light yellow is given light in tone, and the darker blue is dark in tone.

Your committee have examined the recorded state of the art at the time of Mr. Ives's publication of his process, and have satisfied themselves that it is the first working, practical process of photographing colors in their relative degree of light and shade as they impress the eye, and that Mr. Ives is entitled to high commendation *for the complete publication, in all its details*, of his process, as well as the high degree of perfection of the results obtained, certainly unequalled up to that time, and unsurpassed, if equalled, up to the present time.

The principle of rendering colors photographically according to

their visual intensity had been proposed before Mr. Ives's publication. Mr. Ives seems to have been the first who made successful application of the principle, in his perfected and published process, which deserves recognition by reason of its novelty, its completeness, and the publication of it without any reservation of information or of rights. In consideration of which, and as a fitting recognition of the benefit bestowed on the art by Mr. Ives, your committee recommend the award of "THE SCOTT LEGACY MEDAL AND PREMIUM" to Mr. FRED. E. IVES, for his chlorophyl process of photographing colors according to their visual intensity.

All of which is respectfully submitted.

COLEMAN SELLERS, *Chm.*,	JOHN G. BULLOCK,
JOHN SARTAIN,	W. CURTIS TAYLOR,
SAMUEL SARTAIN,	FREDK. GRAFF,
JOS. M. WILSON,	CHAS. F. HIMES.

Approved August 4, 1886.

H. R. HEYL, *Chairman.*

APPENDIX.

Notes upon Ives's Process of Isochromatic Photography, comprising the Record of Experiments on the same, conducted by F. E. Ives, in presence of Fredk. Graff, Jos. M. Wilson and John G. Bullock, June 16, 1886.

PROCESS.

Emulsion Used.—Newton's collodio-bromide. Preferably ripe. Fresh is apt to fog. The rapidity of this emulsion is about one-third that of a bath plate in sunlight.

Chlorophyl.—That obtained from blue myrtle or common plantain is preferred. That from the plantain appears to be relatively more sensitive for red than that from myrtle, although the admixture of eosine seems to correct it.

Upon this occasion, Mr. Ives used about equal parts of each, probably one ounce altogether, cut and digested in five ounces Atwood's ninety-five per cent. alcohol, on water bath for about fifteen minutes. Filtered and ready for use; should be allowed to cool.

(*From an Ives Isochromatic Photograph of a Chromo-Lithograph.*)

Subject.—" The Midnight Sun at the North Cape."

IVES PROCESS OF ISOCHROMATIC PHOTOGRAPHY.

(From an Ordinary Photograph of a Chromo-Lithograph.)

Subject.—" The Midnight Sun at the North Cape."

IVES PROCESS OF ISOCHROMATIC PHOTOGRAPHY.

The plate having been coated with the collodio-bromide emulsion is allowed to set; it is then flowed over five or six times with the alcoholic solution of chlorophyl and immersed in a dish of water, which seems to precipitate the chlorophyl in a very finely divided condition upon the collodion, rendering thereby the plate very sensitive, which it is not, if exposed without the immersion in water.

That chlorophyl remains upon the plate is demonstrated by the fact that after coating a plate so treated with an alcoholic varnish, the last drippings are of a green color.

Fresh myrtle leaves should be used, as the sensitizing properties decrease with age.

Eosine.—About one drachm of a stock solution of eosine, blue shade, thirteen grains to the ounce, ninety-five per cent. alcohol are added to three pints of water, giving a pale cherry red color to the same. The plate is immersed in this solution for about one minute, for the plain eosine plate, and *directly* after flowing with the chlorophyl in the chlorophyl-eosine plate, *without previous washing*, that the two coloring matters may be deposited together.

It does not answer the purpose so well to add the eosine to the chlorophyl solution and then flow the plate.

The yellow sensitiveness in the plain eosine plate may be somewhat increased by a slight action of silver nitrate, *but not where chlorophyl is present.* Free silver salt is destructive to chlorophyl sensitiveness.

An excess of eosine slows a plate. It renders an emulsion sensitive to yellow and green, but not to red, and requires a darker shade of yellow screen for the best results.

Screen.—A solution of picric acid in a small tank, with sides of plate glass: thickness about one-fourth inch between glasses; such was used in the following experiments. A more convenient screen is made by flowing a piece of plate glass with gelatine, staining it with picric acid, and covering with glass, previously flowing with Canada balsam. Such may also be introduced between the combinations of a double lens.

Development.—Soda carb. and soda sulphite with *dry* pyrogallic acid.

The usual stock solutions of pyro., made with sulphurous acid, etc., should not be used. A little bromide is also added. All

forms of these plates develop very quickly. Are likely to fog and may be intensified, but still give good prints. Fumes of H_2S are very destructive. A dark, yellow-green glass, gives the safest light for development of chlorophyl plates.

Subject.—A lithograph containing red, blue, yellow and green in pure colors, and combinations thereof.

FIRST EXPOSURE.

Plate.—Plain collodio-bromide emulsion. Time, one minute; diffused light by window and under skylight. *No color screen.*

Developed quickly, about correct time.

SECOND EXPOSURE.

Plate.—Plain collodio-bromide, *with color screen.* Time, one minute; in sun light reflected from mirror.

Developed. No trace of image. Entirely under exposed.

THIRD EXPOSURE.

Plate.—Chlorophyl. Time, seventy seconds; reflected sun light. Over exposed. Yellow screen used.

FOURTH EXPOSURE.

Plate.—Chlorophyl. Time, forty-five seconds; reflected sun light. Correct exposure. Screen used.

FIFTH EXPOSURE.

Plate.—Eosine. Screen used. Time, forty-five seconds; reflected sun. Correct exposure.

SIXTH EXPOSURE.

Plate—Eosine and chlorophyl. Screen used. Time, *fifteen seconds*, reflected sun light. Exposure correct. Best negative of all.

Comments:—A chlorophyl plate exposed without a yellow screen would be full of detail, but the reds would be too dark and the blues too light.

Mr. Ives claims to be the first to *prove* that the chlorophyl plate produces all colors in their correct relations. The first to prove blue myrtle chlorophyl to be the best of chlorophyls. The first to *combine* eosine and chlorophyl. The only one to give the process to the public.

The relative values of the different sensitizers are demonstrated by the accompanying prints, and those of the spectrum.

Their effect upon the length of exposure rendered necessary, is shown by the list of exposures above given.

In our opinion, Mr. Ives demonstrated, with satisfactory results, all that he claims for his process, which we believe to be an eminently useful one, and one, which, with ordinary care and attention to the instructions, is by no means difficult to manipulate.

[Signed] FREDK. GRAFF,
JOS. M. WILSON,
JOHN G. BULLOCK.

REPORT OF THE JOINT COMMITTEE OF THE FRANKLIN INSTITUTE AND AMERICAN RAILWAY MASTER MECHANICS' ASSOCIATION, TO INVESTIGATE THE HAMMER-BLOW, OR MAGNITUDE AND VARIATION OF PRESSURE, OF LOCOMOTIVE DRIVING-WHEELS, ON THE RAILS OF A RAILWAY.

MEMBERS OF THE JOINT COMMITTEE.

FRANKLIN INSTITUTE.

Edward Longstreth, M. E., Philadelphia, Pa.
Coleman Sellers, M. E., Philadelphia, Pa.
T. N. Ely, M. M., Altoona, Pa.
P. H. Dudley, M. E., New York.
T. Shaw, M. E., *Chairman*, Philadelphia, Pa.

AMERICAN RAILWAY MASTER MECHANICS' ASSOCIATION.

William Woodcock, M. M., Elizabeth, N. J.
Professor S. W. Robinson, Columbus, O.
Angus Sinclair, M. E., Chicago, Ill.
T. L. Chapman, M. M., Richmond, Va.
Charles Blackwell, M. M., Roanoke, Va.
F. W. Dean, M. E., Scranton, Pa., *Secretary*.

T. Shaw, M. E., *Chairman*.
F. W. Dean, M. E., *Secretary*.

Your committee respectfully report that they have held meetings from time to time, extending over a period of eight months, and have written to and kept informed any absent members, in order

that all could have a correct understanding of the work and give written suggestions where their presence was impracticable.

The committee being composed of professional men, on active duty in different portions of the United States, it was possible to assemble only one-half of its members at any one time.

The work of the committee, though of a seeming simple character, was in a measure problematic, and in a direction that has occasioned much diversity of opinion amongst leading engineers and scientists, many of whom contend that there is no wave force, or so-called hammer-blow, from imperfect balancing, etc., while some of our Master Mechanics maintain that their locomotive driving-wheels are in perfect balance, etc.

It is, however, self-evident upon careful observation, that, to balance any vibrating weight moving in a horizontal plane, by counter-weights in the crank-wheel moving in a vertical plane of rotation, that wherever the balance is made perfect in the horizontal direction, it is out of balance in the crank-wheel in a vertical direction equal to a large portion of the counter-weight employed to correct the horizontal movement. In view of this fact, we find that engines considered most perfectly balanced by counter-weights in the crank-wheel, do occasion great disturbance in a vertical direction (causing a wave force, that may be compared to a hammer-blow), that has a measure of destructiveness upon rails and bridges dependent on weight and velocity of moving parts, and that it is worthy of the most careful examination and test. The forces induced on both sides of the engine, from this cause, are of a complex character, varying greatly, under modifying conditions that occur in practice, and do not submit readily to calculation.

We deem a test of this peculiar action of such importance that we recommend that it be subjected to accurate measurement by means of a special dynamometer that your committee has specially devised, and which we believe is competent for the purpose. We believe also that it will give a correct showing of the complicated and destructive force complained of, and show its exact value, and may perhaps indicate the application of such remedies as may hereafter be found necessary to provide to correct any evident damage in the direction referred to.

A description of the proposed dynamometer is hereto annexed, the cost of which, erected in place exclusive of ground, but cov-

ered by a frame building, is estimated to be $6,000. Your committee having performed their services gratuitously, are not expected, of course, to provide the ways and means to procure the proposed test apparatus.

It has been suggested, however, since the advantage of any test would be with the railroad companies, that possibly these companies would unite in providing the needful apparatus, and that in case it was provided as described, the FRANKLIN INSTITUTE might be intrusted with the custody and possible ownership of the same for the use of all railroad companies. The above estimate includes the expense of Prof. P. H. Dudley's recording apparatus.

For the Committee. { THOMAS SHAW, M. E., *Chairman.* F. W. DEAN, *Secretary.*

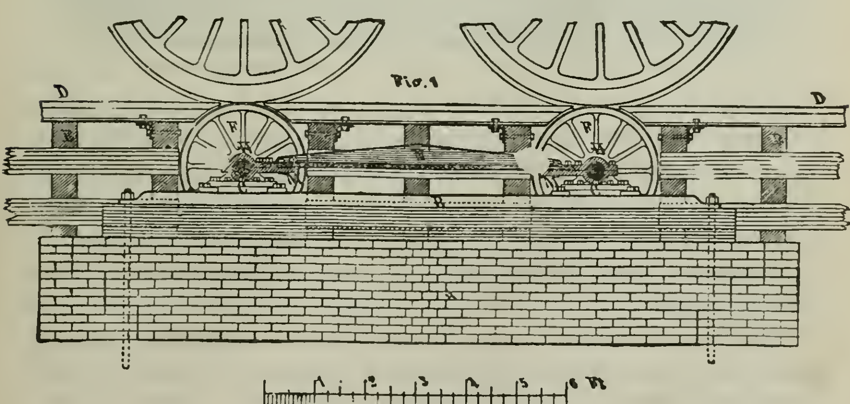
May 31, 1886.

Approved by the Committee on Science and the Arts, September 1, 1886. H. R. HEYL, *Chairman.*

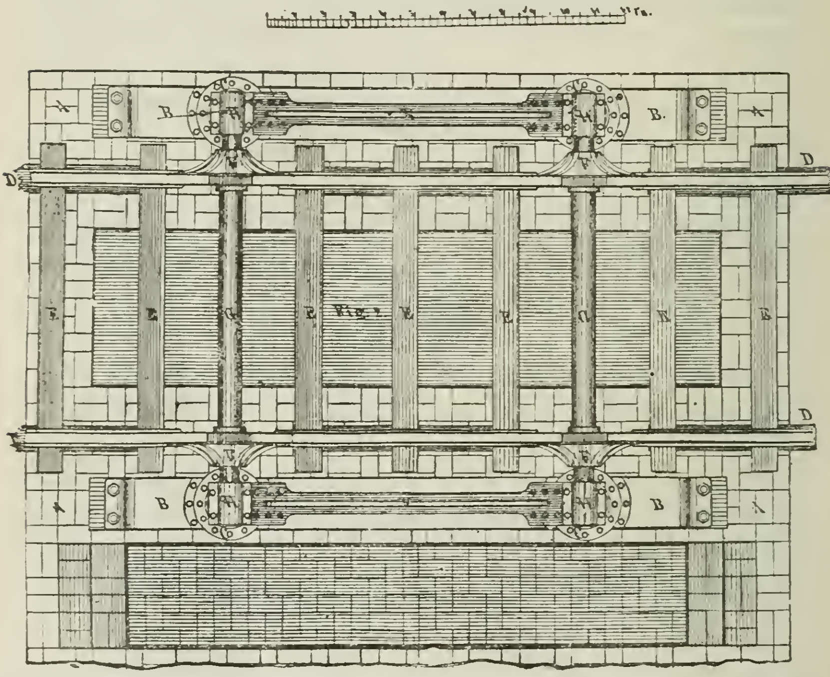
APPENDIX.

DESCRIPTION OF SKETCH OF DYNAMOMETER FOR TESTING THE HAMMER-BLOW OF LOCOMOTIVE DRIVING-WHEELS, ON THE RAILS OF A RAILWAY.

Fig. 1, represents side view of dynamometer in position, with locomotive drivers in place for testing; *Fig. 2*, shows a top view of the same; *Fig. 3*, represents a vertical section through the centre of hydraulic chamber, disc, etc. Similar letters refer to similar



parts, of which *A* represents brick foundation, to which is secured cast iron bed-plate *B*, upon which is supported the dynamometer *C*. Ordinary rails, *D*, are secured to sleepers, *E*, to enable the locomotive to propel itself into position upon the dynamometer wheels, *F*. Said wheels *F*, are solid wheels with little or no elasticity, mounted securely on axles, *G*, running in journals *H*. Said journals form the upper part of disc, *I*, which is free to move vertically in cylinder ring *J*, the said ring *J*, being held in concentric position with the base-plate *K*, by projecting rib *L*. The base-plate *K*, rests upon the planed surface



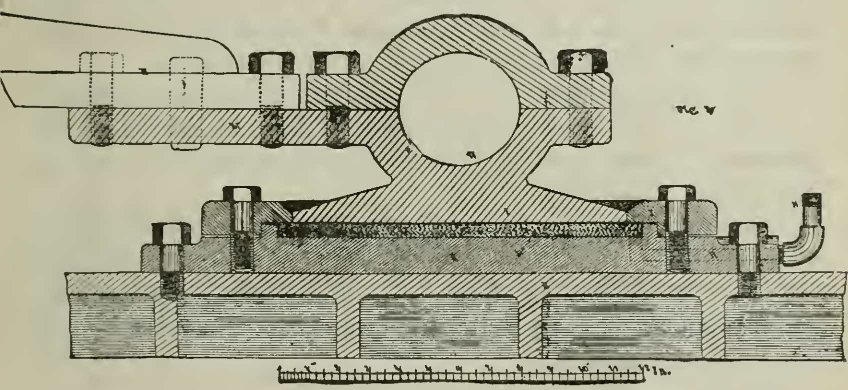
of bed-plate *B*, and is capable of adjustment in a longitudinal direction, and is secured in position by tap bolts shown. The journals *H*, are provided with a projecting rib *M*, pointing inwards, to enable the bolting of a cast iron tie-rod *N*, between said journals. The rails *D*, are fashioned on the ends next to wheels *F*, to suit configurature of wheel, allowing sufficient play, not to come in contact with the same.

The hydraulic disc *I*, has a diameter of eleven inches = area of ninety-five square inches. This disc is turned to fit smoothly and freely into cylinder ring *J*, supported by half inch depth of fluid

(glycerine and water) in chamber *O*. Leakage is prevented at periphery of disc by a thin sheet of pure rubber *P*, which is a diaphragm for bridging the crevice at said periphery, as shown in sketch. This causes the full load to rest solidly upon fluid, with the slightest possible motion and the minimum friction. A passage-way is bored in base *K*, at *R*, for attachment of indicator, or gauge, at *S*. The indicator used in this case must be provided against leakage.

The writer having had occasion to use hydraulic discs of this character for dynamometers for other purposes, finds this method to possess all the accuracy of a pivoted lever in a platform scale; in fact, it works hand in hand with a platform scale.

When a locomotive driver is caused to rest upon the dynamometer, it will give the correct weight of the same, and if said driving-wheel be caused to revolve with any variation in the load occasioned



by imperfect balancing or otherwise, the dynamometer through its indicator, will give correct indications of all such variations, at all speeds where ordinary indicators can be used. The indicator in this case will have the pencil operated from any suitable crank motion on the said driving-wheel, enabling a card to be taken for each half revolution of said wheel, which card will show correctly the pounding force or hammer-blow, fulfilling the purpose your committee have in view.

The locomotive during trial is secured firmly in position, to prevent any longitudinal movement. This can be done by providing heavy bumper timbers on the forward end and clamping engine in position with centres of drivers over centres of the dynamometer wheels.

THOMAS SHAW, M. E.,
Chairman of Joint Committee.

"HYPOTHESIS," OR "ASSUMPTION?"

Professor De Volson Wood's discussion of the properties of the luminiferous æther is so important and valuable, that I am glad to welcome his defence. on p. 226 of the current volume of this JOURNAL, against my charge on p. 129, even though it proceeds upon a mis-interpretation of the real point at issue between us. "The charge of overlooking Herschel's hypothesis," which I did *not* make, is a very different thing from the charge of "overlooking the precaution which Herschel had taken to define his hypothesis," which I *did* make. "The *assumption* that the density of the æther was the same as that of the air at sea-level," which Prof. Wood alleges against Herschel is very different from the "hypothesis that an amount of our ætherial medium equal *in quantity of matter* to that which is contained in a cubic inch of air were enclosed in a cube of an inch in the side," which Herschel uses as the basis of a conditional estimate of ætherial eslasticity.

Prof. Wood considers the statement that he proceeds precisely according to Herschel's methods and obtains results which are substantially the same as Herschel's, "questionable as to the correctness of the facts."

Herschel's reasoning, as well as Prof. Wood's, is based upon the relations of wave-velocity to elasticity and density, which are expressed by the formula $v^2 \propto e \div d$. Representing the velocities of sound and of light by v_1 and v_2, respectively, Herschel's fundamental equations were,

$$v_1 = \sqrt{gh} = 916 \text{ feet.}$$

$$v_2 = 186{,}000 \text{ miles.}$$

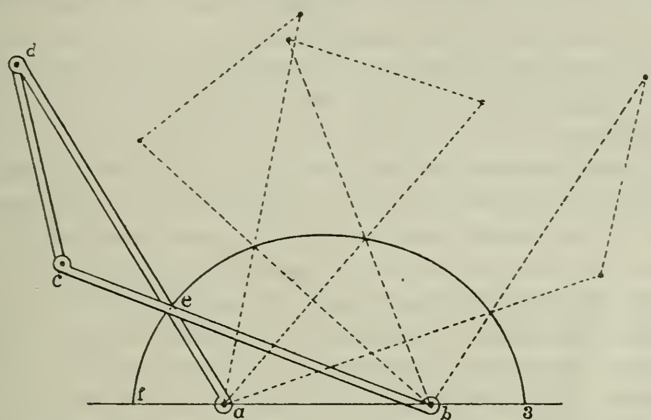
$$e_1, \div d_1, : e_2 \div d_2 :: v_1^2 : v_2^2 :: 1 : 1{,}148{,}000{,}000{,}000.$$

Prof. Wood says that "in a pound of the æther there is 100,000,000,000 times the kinetic energy of a pound of air." The discrepancy arises from his inadvertently omitting one cipher and making a rougher approximation than Herschel. The difference of approximation causes a similar slight discrepancy between the two estimates of the ratio when allowance is made for the thermodynamic acceleration of the velocity of sound, Wood's result being 8×10^{11} nearly, while Herschel's is 811,801,000,000; the methods of calculation being the same.

PLINY EARLE CHASE.

A NEW ELLIPSOGRAPH.

There are so many ellipsographs and methods for drafting the ellipse, that a new one can hardly be said to be called for, but the study of the curve is interesting to many from a purely theoretical point of view, and the following device may be new to the subject. It is new to me, both as to its mechanism and its principle.



Four links, *ab*, and its equal, *cd*, *bc*, and its equal, *ad*, are joined together as in the figure, the points *a* and *b* being fixed. As the system is moved about the fixed centres, the intersection of the two crossed links will follow the outline of an ellipse, *fg*, which has the two centres for its focii, and the link *ad* for its major axis.

The figure shows the instrument in rough outline, to illustrate its principle only, but it is easy to see that it would be adjustable for different ellipses if the centres were mounted on sliders, or otherwise made movable on the bars. It would also be a simple matter to attach a double slider that would slide on both the crossed bars and hold a pencil point at their intersection.

Maplewood, Mass., August 29, 1886. GEORGE B. GRANT.

TELEPHONIC TESTS OF ELECTRIC FUSES.—Ducretet rapidly tests the quality of electric fuses of perhaps 1,000,000 ohms resistance, by passing the current from three Lechanché elements through a telephone, the fuse, a coil of fine wire, and circuit-breaker. If the resistance of the fuse be too great, nothing is heard in the telephone when the current is broken or closed ; if too small, the telephone makes a deafening noise ; if just right, the telephone sounds faintly.—*Comptes Rendus, May 24, 1886.*

HENRY P. M. BIRKINBINE.

The subject of this memorial was born at Reading, Pa., May 21, 1819. He was deprived, by the death of his father, of many educational advantages, and thrown largely upon his own resources. He learned the machinist's trade, and, while still at the bench, devoted his leisure hours to self-instruction in geometry, trigonometry and the higher mathematics. He was engaged for a number of years in constructing mill-machinery, pumping machinery, etc., some of which works were connected with the earlier developments of our great anthracite coal region. He also leased a forge, and carried on the manufacture of augurs near Reading.

In 1845, Mr. Birkinbine came to Philadelphia. Here he engaged at first in the manufacture of hydraulic rams, establishing himself at Broad and Vine Streets, but subsequently removed to Front and Arch Streets, where he formed the partnership of Birkinbine & Martin (afterwards Birkinbine & Trotter), doing a general machine business, but giving special attention to hydraulic machinery. Among the important works built by the firm, for its own account, or under contract, may be named the Gas-works and Water-works for Germantown (erecting the first stand-pipe in America); the West Philadelphia Water-works—the Bull Cornish Engines being designed and erected in their shops; the pumps and Water-works of York, Pa., and other towns; and considerable work for exportation, chiefly to the West Indies.

After the dissolution of the firm above named, Mr. Birkinbine, for some years, continued the same business, and, for himself and others, constructed numerous public water- and gas-works, and heating and ventilating apparatus for hospitals and public institutions.

Mr. Birkinbine was chosen Chief Engineer of the Philadelphia Water Department in 1857, and served in this office from 1858 to 1861, and again from 1864 to 1866 inclusive. While occupying this position, he built the new wheel house and pumps at Fairmount, repaired the dam at Fairmount, made exhaustive tests of turbine wheels (in 1861), constructed the Roxborough reservoir and pumping works, raised the Corinthian Avenue reservoir to equalize the water storage, laid large feeding mains and built the

water-tower and arch at Fairmount. During the construction of the latter, he received injuries from which he never fully recovered, and which undoubtedly shortened his life.

During his administration as Chief Engineer of the Water Department, Mr. Birkinbine investigated the subject of the future water supply of Philadelphia, and prosecuted preliminary surveys as far as the funds appropriated would permit. His conclusions are embodied in a special report to the City Councils, dated 1865, in which he recommended the utilization of the drainage area of the Perkiomen Creek and bringing the water by aqueduct to the city.

After his retirement from public office, Mr. Birkinbine engaged in private practice as a hydraulic engineer, and was employed as consulting or constructing engineer upon a number of works, public and private, some of which were of importance. During this period of his career, he was employed temporarily as General Manager of the Camden Iron Works.

Mr. Birkinbine's inventions were numerous, and comprised, among others, an improved hydraulic ram; a water-cushion, double-beat valve for pumps, and a system of fire-protection for cities and towns, which embraced the feature of permitting a change from the reservoir to direct pressure, by the employment of valves moved by air compressed by the static pressure of the water supply. This system is at present in use in a number of cities and towns.

Mr. Birkinbine's published works were chiefly in the form of reports or papers. The more important of these were his reports as the Chief Engineer of the Philadelphia Water Department, which form nine annual volumes; his history of the Philadelphia Water-Works, and his reports on the water supply of Harrisburg, Reading, Allentown, Lebanon, Lancaster, Bethlehem and other cities. Mr. Birkinbine had made himself master of the subject of water rights, and his services were frequently called in requisition in important legal cases—among the notable cases in which he was engaged was that of the Schuylkill Navigation Company *vs.* the City of Philadelphia.

Mr. Birkinbine became a member of the FRANKLIN INSTITUTE in March, 1845, and sometime later became a life member; and for many years took an active share in its work. He was elected to the Board of Managers in 1851, and served in that capacity from 1851 to 1856.

The following is a list of his contributions to the JOURNAL OF THE FRANKLIN INSTITUTE, viz:

Birkinbine, H. P. M., and Trotter.—"West Philadelphia Water Works Stand-Pipe," lix, 210.

Birkinbine, H. P. M., "Economy of Using Steam Expansively," lxxiii, 34.

"Pumping Engines," lxxxvii, 323; lxxxviii, 109.

"Stand-Pipe for Bloomington, Ill.," c, 234.

"Rainfall in the Schuylkill River Basin," ci, 185.

"The Schuylkill River," ci, 321.

"Relative Cost of Steam and Water-Power," cv, 47.

"The Future Water Supply of Philadelphia," cv, 305; cvi, 38; cviii, 297.

Personally, Mr. Birkinbine was a man of positive convictions, thoroughly in earnest in everything he advocated and undertook. He leaves behind him the record of a busy, an active and useful life. At the time of his death, which occurred on the twenty-first of April, 1886, he had almost completed his sixty-seventh year.

W. BARNET LE VAN, *Chm.* WASHINGTON JONES,
JOHN H. COOPER, C. CHABOT.

EMILE FRANCOIS LOISEAU.

Our late fellow-member, Emile François Loiseau, died at Brussels, on the thirtieth day of April, 1886, in the fifty-fifth year of his age. He was a native of Belgium, in which country he received an education to prepare him for one of the learned professions; but, becoming dissatisfied with the sedentary pursuit selected for him, he withdrew from college and commenced a business life of congenial and active character. He served for eight years in the French army, participating in the Crimean campaign. He was then upon the editorial staff of a Parisian journal, and subsequently became superintendent of an industrial works in Belgium. Whilst in that position his liking for mechanical pursuits so developed, as to determine his future life-work. It was during this period that his attention was drawn towards the immense deposits of coal waste at the Belgium mines, which were constantly increasing, as

the processes then in vogue were imperfect and unequal to the requirements. To the problem of utilizing this waste material, Mr. Loiseau devoted his earnest and intelligent efforts, and devised a process, with the necessary machines, which would more rapidly put it into convenient sized lumps for domestic or steam users' consumption. As the European field was partially occupied, he concluded to introduce his method into the United States, and began operations near Nashville, Tenn., but soon removed thence to Pennsylvania, which promised a wider field and better market, and for the reason that his plans had won the favorable regard of several extensive coal operators in the anthracite region. At Mauch Chunk, the first experimental machinery was built, and gave such satisfactory results, that a company was formed for the purpose of utilizing the great mounds of coal waste to be found in Pennsylvania. About this time (see this JOURNAL, January, 1874,) Mr. Loiseau read before the FRANKLIN INSTITUTE a highly interesting paper upon the manufacture of "Artificial Fuel," in which he described the processes and machines in use up to that date. In furtherance of the intentions of his company, Mr. Loiseau designed, and had built at Mauch Chunk, a machine capable of making 100 tons of compressed fuel per day in lumps of the shape and size of hen's eggs. In this machine he embodied what he considered to be good in existing machines, and supplemented it with some important details of his own devising. When completed, it was erected at Port Richmond, near the coal wharves of the Reading Railroad Company, at which point it was expected coal dust could be had in quantities. After the delays and mishaps inseparable from new enterprises, and which were borne by Mr. Loiseau with indomitable courage, the apparatus, with such modifications as later experiences had taught, was got into such excellent working condition as to yield about eighty tons per day of ten hours of agglomerated anthracite dust of dense, non-friable and weatherproof qualities, which met with a ready sale at a price but little below that of natural lump coal. Unfortunately at this juncture, the buildings took fire and were totally consumed. Previous to this disaster, when the success of his methods had been assured and patented in the European countries, Mr. Loiseau had entertained proposals made to him, by some important coal companies in France and Belgium, to erect his machines at their mines, and

as the destruction of the works at Port Richmond, and the inability to procure coal dust at that locality in quantities and at desirable prices, influenced his company against rebuilding, Mr. Loiseau then determined to accept a proposition made to him by a Belgian coal mining company at Ham-sur-Sambre, and had built in Philadelphia and shipped to Belgium, the patented parts of a machine capable of compressing twenty tons of dust, accompanying them to superintend their erection and operation, and to demonstrate the practicability of his process. It reached the mines, but, unfortunately, was not put up, as the strike of the Belgium miners soon after took place; hastened, perhaps, by the anticipated loss of employment from the use of such a labor-saving machine. The more valuable parts taken from the United States were hidden under coal dust to preserve them from the fury of the mobs. This derangement of his plans, with threats of violence directed against his person, added to general ill health, brought upon him an acute attack of sickness, which terminated his life at the time when his many years of persevering efforts seemed on the verge of securing for him the substantial reward they merited.

WASHINGTON JONES, *Chm.*, W. BARNET LE VAN,
C. M CRESSON, M. D., WM. H. WAHL.

JOAQUIM BISHOP.

JOAQUIM BISHOP died on the 8th of August, 1886, in the eighty-third year of his age.

Mr. Bishop was a pioneer in the manufacture of platinum in the United States. Born of English parents, in Portugal, in 1804, he came with them to Baltimore in 1810, leaving Portugal, where his father was engaged as Director of a department of Government work, on account of the invasion of the peninsula by the armies of Napoleon.

After a residence of one year in Baltimore, the family removed to Philadelphia.

At the age of twenty-two, Mr. Bishop entered as an apprentice to the jewelry business, but soon after changed his vocation to that of a finisher in a brass foundry.

In 1832, he engaged with Prof. Robert Hare, as an assistant, at the University of Pennsylvania. While in this position, his attention was attracted by the experiments of Prof. Hare with the

oxyhydrogen blow-pipe. The melting of platinum was done by Prof. Hare, on a limited scale, for commercial purposes.

In 1839, Mr. Bishop commenced business as a manufacturer of philosophical instruments, on Laurel Street, removing, in 1851, to Pear Street, adding to his business the melting and working of platinum. This department increased to an extent which induced him to devote his attention entirely to it. Removing, in 1858, to Radnor, in Delaware County, he again, in 1865, changed his location to Sugartown, in Chester County. At the latter place, he erected a commodious laboratory and work-shop.

At the exhibition of the FRANKLIN INSTITUTE, in 1845, he received a premium for his exhibit of platinum ; and at the Centennial Exhibition of 1876, he was the only exhibitor of platinum work done in the United States, for which he received a medal and diploma. C. B.

Franklin Institute.

[*Proceedings of the Stated Meeting, held Wednesday, September 15, 1886.*]

HALL OF THE INSTITUTE, September 15, 1886.
CHAS. H. BANES, President, in the Chair.

Present—146 members and twenty-one visitors.

The election to membership of twelve persons was reported.

The special committees charged with the duty of preparing memorials of EMILE FRANÇOIS LOISEAU and HENRY P. M. BIRKINBINE, lately deceased members, presented reports, which were accepted and referred to the Committee on Publications.

The Chairman of the Committee on Science and the Arts reported the recommendation of the committee for the award of the ELLIOT CRESSON MEDAL to EUGENE H. and ALBERT H. COWLES, for their "invention of a new process in the metallurgical arts for the reduction of refractory substances ;" and of the JOHN SCOTT LEGACY PREMIUM AND MEDAL to the same inventors, for their "Electric Smelting Furnace."

The recommendations were severally approved, and the Secretary was directed to take the usual measures to carry them into effect.

A communication was presented from PAUL LA COUR, of Copenhagen, Denmark, touching the recent award to PATRICK B. DELANEY, of New York, of the ELLIOT CRESSON MEDAL, for his "Improvements in Multiplex Telegraphy." Action thereon was deferred.

Mr. S. LLOYD WIEGAND read a brief communication, descriptive of "Schaefer's Compound for Improving the Quality of Steel," and exhibited the operation of the process and specimens. The compound is a mixture of linseed oil, resin, glycerine and carbon.

The Secretary's report included remarks on recent progress in electric smelting; a description of the Brush "Colossus," a dynamo-electric machine of great power, built for the Cowles Electric Smelting and Aluminum Company, for their electric smelting works, at Lockport, N. Y., together with the record of the trial tests of the same; and on the recent earthquake on the Atlantic border of the United States. In this connection, there were shown numerous illustrations, exhibiting the ruins of the city of Charleston.

PROF. E. J. HOUSTON offered some remarks on earthquake phenomena in general.

The Secretary exhibited and described the "Twin-Sheave System for Electric Cables and Wires," the invention of Messrs. Fondersmith & Wilson, of Philadelphia, which is claimed to be adapted for the reception and carrying of cables and wires underground, on the surface, against walls, through tunnels, or elsewhere, where facility is wanted for readily drawing cables in or out.

The meeting then proceeded to the final consideration of some proposed amendments to the By-laws, and was thereupon adjourned.

WM. H. WAHL, *Secretary.*

BOOK NOTICES.

RECENT PROGRESS IN CHEMISTRY. An Address prepared at the Request of the New York Academy of Sciences, and read March 15, 1886. By H. Carrington Bolton, Ph. D., Professor of Chemistry, Trinity College, Hartford.

This most interesting and valuable résumé of the world's advancement in one of the most fruitful as well as most difficult lines of research, is conceived in the spirit of Hofmann's *Introduction to Modern Chemistry*, of over twenty years ago. It is a scholarly though plain statement of the progress of chemistry as seen to-day by the eye of one of the masters of the science.

Professor Bolton has long since won the admiration and received the thanks of the chemical world for his pains-taking labors in collecting the widely scattered data in chemical literature bearing upon special branches of the subject. In this treatise, he gives a general view over the whole field, and in spite of his scientific caution and studious avoidance of the defect of merging the horizon of cloud with the horizon of earth, he does not conceal the commendable and cheery exultation of a worker in viewing the present state of the structure he has helped to rear.

This essay can be heartily recommended to the general reader as well as to the professional chemist. Each will be gratified and astonished at the census; indeed, the latter is likely to experience these emotions more than the former unless, which is unlikely, he shall have taken considerable time from his own investigations to obtain the information which Professor Bolton here gives. The discourse is divided into twenty-two paragraphs, and is followed by seventy-eight citations of authority for its various statements. Nos. 1 and 2, deal with the artificial difficulties of chemistry and the large number of workers in that field; No. 3, glances at the recent list of supposed new elements; No. 4, at the new physical apparatus for chemical discovery; No. 5,

shows the errors which accompany a too blind acceptance of Prout's law, and reclaims for Professor Cooke, of Harvard, the priority of announcing the variations in the amount of chemical energy expressed by an atomic weight; 6 and 7, treat the discovery by Mendelejeff and others, of the periodic law of elements and the prophecies that have been made and verified, and Dr. Carnelley's hypothesis that all elements are compounds of carbon and æther; 8, 9 and 10, present an interesting survey of the modern views of catalytic action, or that in which a third body causes chemical changes in which it does not participate, together with examples of the indifference to each other of various bodies at low temperatures, which are types of violent affinity at ordinary temperatures; 11, 12, 13 and 14, are taken up with a summary of the work done on the interesting border line between chemistry and physics; 15, apprises us of the recent enlargement of the field of manufactures in inorganic, and 16 and 17, in organic chemistry; 18 and 19, urge the claims of diagrammatic chemistry, and the author boldly deals with open and closed chains of molecules, with hexagons, etc., as if there were no chemical old women in the world to be shocked; 20, tells us what progress has been made in imitating plant products in the laboratory, and 21, frankly avows the standstill in animal chemistry. In the concluding paragraph, these words occur: "The tendency of modern research in chemistry is to magnify the atomic theory; the rapid accumulation of facts, the ever increasing ingenious hypotheses, the most searching examinations of co-ordinate laws, all tend to strengthen the Daltonian adaptation of the philosophic Greeks. Here and there a voice is raised against the slavish worship of picturesque formulæ; but against the molecular theory underlying the symbolic system so depicted, few earnest arguments are advanced," etc. What will those eminent gentlemen, who still retain belief in the continuity of matter and the futility of all attemps to specify its units, say to this?

THE ECONOMICAL ASPECTS OF AGRICULTURAL CHEMISTRY. An Address before the American Association for the Advancement of Science at the Buffalo Meeting, August, 1886. By Harvey W. Wiley, Vice-President Section "C." Cambridge: John Wilson & Son, 1886.

In this pamphlet of thirty-seven pages, the Chairman of Section "C" gives an extended view of the field of agricultural chemistry at present covered by active workers. One can see from this panorama the same energetic research, the same intelligent war upon what seem at first insuperable difficulties, but which are sure to be overcome in the end; and even (by reading between the lines) the same jealousies and reclamations which make up the characteristic scenery of vigorous inductive science. The former and worthier motives may be compared to the "nitrifying organisms," which are so frequently alluded to in the address; and the envy and all uncharitableness which appear in the disputes of eminent men over the question as to who first or most discovered a fact since proved to be important, to the "denitrifying little corpuscles," which co-exist with their opposites in the same plant and serve the general purpose of Nature by undoing or trying to undo all that the latter have accomplished. It is not one of the least merits of Prof. Wiley's address that

it suggests to the reflective mind, that even these very disagreeable creatures (human), which seem to hang about the flanks of the army of investigators like jackals, and to prey on the offal and stragglers, may be shown by analogy to have their uses. The address is divided into a preliminary part, which deals with the statistics of the weights of the products of the soil of the United States each year, and of the ashes of these products; and of the weights of the potash and phosphoric acid in these ashes per year. The next and most important part of the address discusses the part which nitrogen plays in the growth of plants. This leads to the question of how the plants absorb nitrogen and what is the best means of preventing useless waste of this necessary constituent of the proteids and how to increase the supply of nitrogen to the soil. The researches of Pasteur, Schlösing, Müntz, Warrington, Berthelot, Dehérain and Joulie, as well as the observations of Pichard, of Gayon and Dupetit and of Maquenne are ably treated and von Tiegham's "Butyric Ferment" is referred to as probably the "Bacillus amylobcater." Some of the subjects which are taken up under the general head of the "Nitrogenous Food of Plants" are: (1.) Organic nitrogen; (2.) ammonia; (3.) the oxidation of nitrogen due to combustion; (4.) nitrogen oxidized by electrical discharges: (5.) fixation of free nitrogen in soils; (6.) fixation of free nitrogen by the plant; (7.) mineral nitrates; and a short conclusion on the "Future Food Supply." The last paragraphs of this latter portion will serve as an apology for whatever reflections the writer of this has just indulged. "It is probable that all life, vegetable and animal, had its origin in the boreal circumpolar regions. Life has already been pushed half-way to the equator, and slowly but surely the armies of ice advance their lines. The march of the human race is a forced march, even if it be no more than a millimetre in a millenium. Some time in the remote future the last man will reach the equator. *There with the mocking disc of the sun in the zenith, denying him warmth, flat-headed and pinched as to every feature, he will gulp his last mite of albuminoids in his oat-meal, and close his struggle with an indurate hospitality.*"

THE "NOVELTIES" EXHIBITION OF THE FRANKLIN INSTITUTE, 1885.

ABSTRACTS OF REPORTS OF THE JUDGES.

(Continued from page 239.)

PULSOMETER STEAM PUMP COMPANY, NEW YORK.

The New Pulsometer Steam Pump.—This is a double-acting, two-cylinder, lifting and force pump, in which steam acts directly upon the water without the intervention of any mechanical appliances. Steam is admitted into each cylinder through a ball valve at the top, which operates automatically, and closes the passage into one cylinder while it opens it into the other.

Condensation occurs when the valve is closed and water is drawn in by the partial vacuum thereby produced, and at the same time the water in the other cylinder is forced out by the live steam.

When a certain amount of water is forced out of this cylinder, condensation takes place so rapidly that the ball valve rolls over, seals the chamber, and admits live steam into the other cylinder, which has just been filled with water.

From the construction of the pump, it appears that condensation must take place with increasing rapidity from the moment steam is admitted until it is cut off by the rolling over of the valve.

In this valve the ports are close together, and the ball rolls easily from one to the other, thus controlling the admission of steam in a very quick and effective manner.

The water valves are of two kinds, one a plain check with rubber facing, adapted to clean water, and the other a hard rubber ball valve, recommended for sand and gravel.

The feature to which special attention was directed was the new style air valve, used to admit a slight amount of air at each stroke in order to keep the steam and water from actual contact.

The adjusting nut for regulating the admission of air in this valve is held in position by a latch, which catches into notches cut in the nut instead of by a jam nut, as formerly. The change may be readily conceived to be an improvement, but further than this the committee were unable to discover any points of novelty.

The pump is one which recommends itself for its cheapness, simplicity and durability, but without the evidence of a practical test, the committee are unwilling to admit its claim for economy in steam, and make no recommendation.

RAND & HARMER, PHILADELPHIA.

The Siddall Hose-Coupling.—This is an ingenious device for the purpose of quickly coupling hose, and is similar in principle to the old wire stopple for soda water bottles. Its durability will not compare with that of the screw coupling, as the rough usage all hose is liable to get will break off the small pins or lugs to which the lock lever is attached. If this should occur, or the rubber washer slip off, the device is rendered useless.

D. WALKER WEBSTER, LANCASTER, PA.

Water Motor.—This motor consists of an overshot water-wheel on an horizontal axis. The water issues from the inlet passage in one or more small jets, and in a tangential direction to the path of motion, and at a slight angle to the back of the buckets The wheel is driven by the impact of the jets of water against the buckets, and it is doubtful whether much additional power is obtained from the weight of any water remaining in the buckets during the position of a revolution. The centrifugal force throws the spent water to the periphery of the casing, whence it finds its exit at an opening in the bottom. Guards are placed on the inside of the casing over the axle, in order to prevent any drip getting into the bearings. We were unable to make any tests, or to get any reliable data or information as to the efficiency of the motor. The ajutages and buckets are well shaped, and placed in proper relation to each other, and the bearings, needing no packing to keep the water from them, can run with a minimum of friction and can easily be kept in good condition.

WILBRAHAM BROTHERS, PHILADELPHIA.

Rotary Pump, Pressure Blower and Gas Exhauster.—These machines, though differing from each other in some of the details of construction, all depend upon the principle of the well-known Baker blower.

The external housing of each of these machines is a semi-cylindrical iron casting, having flanged outlets on opposite sides for suction and delivery. Concentric with this housing, and revolving freely inside is a hollow drum, carrying two vanes diametrically opposite, which act as the rotating piston. Below are two other drums with openings on one side that permit the passage of the rotating piston, and they are so geared to main drum-shaft as to present their openings to the piston as it advances, revolve with it, and close the passages immediately after, the combination of these two drums always acting to prevent the return of the fluid to the suction pipe.

In the pressure blower and gas exhauster, the journals of the rotary piston and drums are in ends of casing, but in the rotary pump, the shafts pass through stuffing-boxes and bear in pedestals firmly connected to base-plate of the machine; the stuffing-boxes

are so designed that the packing bears against filletted shoulders on the shafts, in order to increase as little as possible the resistance to rotation.

The gas exhauster is used when a very steady flow of gas at low pressure is required, and is usually connected directly to driving engine, and governs speed of rotation by supply of gas. In this machine, the gear wheels for driving the drums are covered with a gas-tight housing. Oil-cups are placed outside, and in such position as to give sufficient head to the lubricant to flow into bearings against internal pressure.

It is the opinion of the committee that the efficiency of these machines should be high, because all the work of forcing the fluid is done by direct pressure, and the motion of the fluid in passing through the pumps is continuous, and with but slight change of direction; and that, as there are no valves, ports or narrow passages through which the fluid has to be drawn, the loss of head due to friction should be small.

The only apparent losses are due to the rotation of the valves, to the friction of the shafts in stuffing-boxes and bearings, and to the leak that might occur around ends and sides of rotating piston.

In regard to wear of working parts, it may be said that, although these machines require to be constructed with great care, and depend, in a great measure, for their effective working upon the accurate setting and fitting of drums and drum-shafts, yet they are so designed that the wear on these parts should be small if proper care be expended upon them.

In consideration of the above, the committee would respectfully recommend the award of— (*A Silver Medal.*)

GROUP 11 *f*.—STEAM BOILERS AND FURNACES.

Judges:—Arthur L. Church, *Chm.*; Griffith M. Eldridge, George A. Vaillant.

The judges, to whom was referred class 11 *f*, steam boilers and furnaces, respectfully report as follows:

The seventy-five horse-power boiler from the Baldwin Locomotive Works, in boiler house, used at and remaining from the Electrical Exhibition of 1884, rendered efficient service throughout the Exhibition. (*Not entered for competition.*)

Two 100 horse-power Harrison sectional safety screw boilers, in

boiler house, fully sustained their well-established reputation in making steam supply for general use of the Exhibition.

(*Not entered for competition.*)

CHALMERS–SPENCE COMPANY, PHILADELPHIA.

Asbestos Manufactures.—This exhibit embraces fabrics of pure asbestos, notably among them curtains for protecting the auditoriums of theatres from injury by accidental fire upon the stage. Also removable steam-pipe and boiler coverings for retarding loss of heat by radiation; both of these inventions are of demonstrated excellence and reliability. The committee recommend them the award of— (*A Silver Medal.*)

GLENMORE IRON FOUNDRY, PHILADELPHIA.

Sectional Furnace Grates, and Supports therefor.—For the economical, durable and convenient properties shown in this grate, the committee recommend the award of— (*A Bronze Medal.*)

C. H. HOLT, PHILADELPHIA.

Fuel Economizer for Utilizing Heat of Products of Combustion in the Flue leading from Boilers to Chimney.—This invention is of the general type of the well-known Green economizer; is of a most durable and substantial construction, and is provided with means for effecting circulation of the water in its tubes.

For excellence of design and workmanship, the committee recommend the award of— (*A Bronze Medal.*)

J. E. LONERGAN & CO., PHILADELPHIA.

Lynde's Safety Valve, Water-feeding Regulator, and High- and Low-Water Alarm for Steam Boilers.—For efficient and reliable action and safety, a diploma of— (*Honorable Mention.*)

E. S. MORSE, PHILADELPHIA.

Feed-Water Heater.—This consists of a horizontal cylinder containing feed-water, and provided with proper inlets, outlets and openings for cleansing. Through this cylinder a series of parallel small tubes pass horizontally, conveying exhaust steam, which imparts its heat to the water and causing precipitation of some of the impurities of the water. For good construction, the committee recommend a diploma of— (*Honorable Mention.*)

WHETSTONE & GRAU, PHILADELPHIA.

J. P. Grau's Feed-Water Heater and Purifier.—For efficiency and

simplicity in heating feed-water and precipitating impurities therein, and thus protecting steam boilers from injury—

(*A Silver Medal.*)

T. E. SUTNER, PHILADELPHIA.

Cooke's Damper Regulator.—This is a diaphragm regulator of the well-known Clark type, protected by a water column from the temperature of the steam, and is operated by steam pressure admitted and relieved by an automatic valve, easily adjustable to any desired steam pressure. For prompt and reliable working in controlling high steam pressures, we recommend the award of—

(*A Bronze Medal.*)

H. B. SMITH MACHINE COMPANY, PHILADELPHIA.

Kellam's Steam Damper Regulator.—This invention is operated by steam pressure applied directly to a piston working with a minimum of friction in a vertical cylinder ; is readily adjusted, and promptly and efficiently controls the steam pressure of boilers working within their proper capacity. It is also applicable to operate valves for controlling reduced steam pressure from a high pressure supply.

For good design and construction, and prompt and reliable working, the committee recommend— (*A Bronze Medal.*)

THOS. Y. DE NORMANDIE, PHILADELPHIA.

Geisler's Smoke Consumer.—This invention was applied to the Baldwin seventy-five horse-power boiler, which was operating economically without it, and did not offer such opportunities to demonstrate a saving of fuel as many of the boilers to which it might be applied.

(See report of Test Committee.)

GEORGE KINGSLEY'S BOILER.

(See report of Test Committee.)

WM. M'ILVAIN'S SONS & CO., PITTSBURGH, PA.

Specimens of Boiler Plate.—Showing the excellent ductility of metal, proved by most difficult flanging, without developing any flaws or defects.

For excellent quality of material— (*A Bronze Medal.*)

APPENDIX TO REPORT OF JUDGES, 11 *f*.

TEST OF THE KINGSLEY BOILER.

PHILADELPHIA, December 7, 1885.

GEORGE A. VAILLANT, ESQ., *Chairman pro tem Section 11 f:*

DEAR SIR:—The sub-committee appointed to test the Kingsley boiler respectfully presents the following report:

On November 6, 1885, a test was made for evaporative efficiency, and on November 7th a test for capacity.

The apparatus used during the test was obtained by Mr. S. Lloyd Wiegand. The scales were standard Fairbank's platform scales, the thermometers by A. Kuchler & Son. The steam-gauge, thermometers, scales, etc., were tested by Mr. W. Barnet Le Van, and corrections made for inaccuracies.

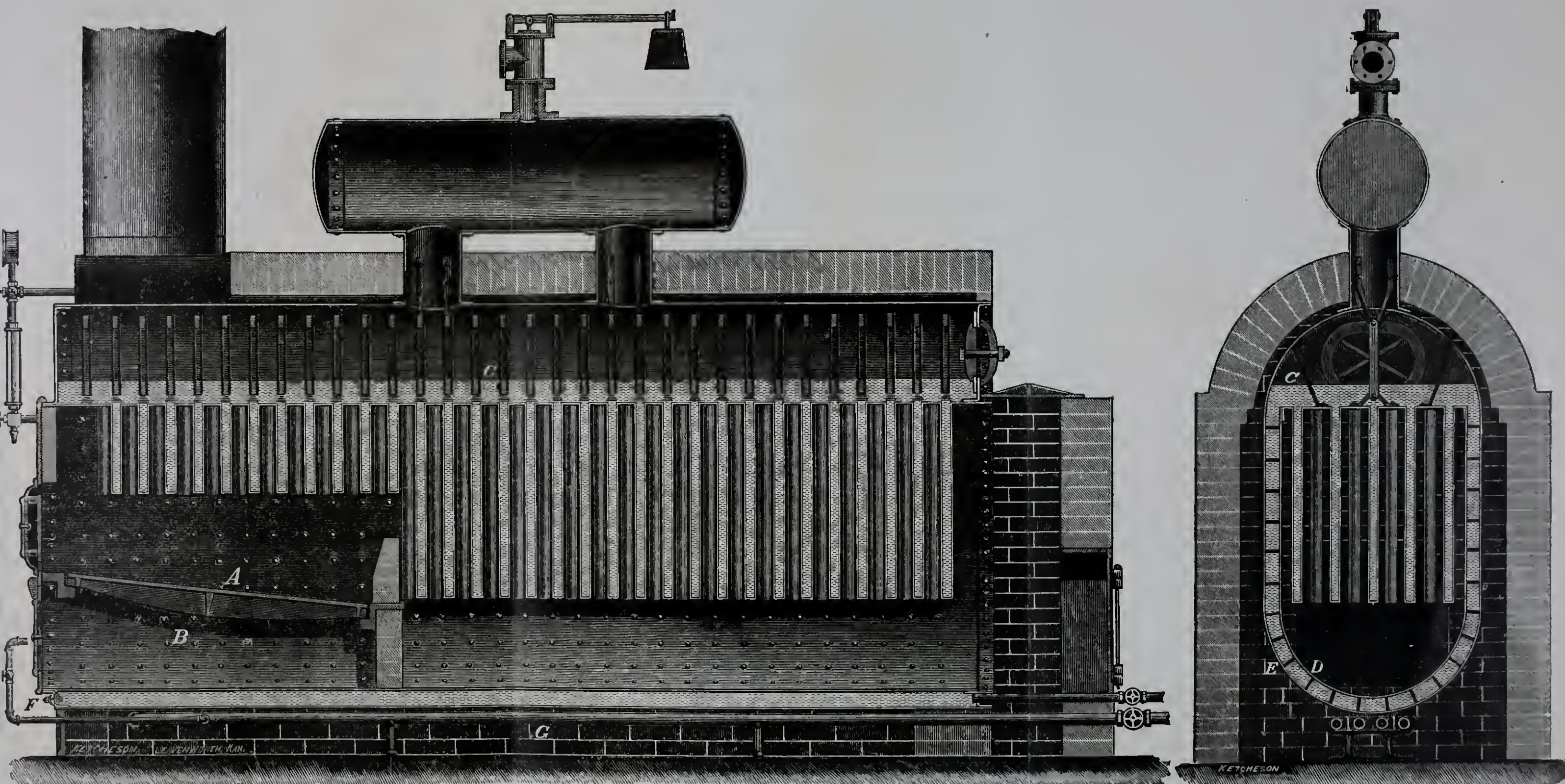
The thanks of the committee are due to Messrs. C. W. Asbury, H. E. Asbury, H. H. Cooke, C. G. Davis, W. C. Lusson, C. S. Martinez, R. M. W. Ridington, G. A. Sulzer, R. Welch, C. M. Wisman, A. H. Wood, W. Henry, of the Spring Garden Institute, who rendered very valuable service in taking data.

In making the tests, steam was first raised to the required pressure, when the fires were quickly drawn and the ash-pit cleaned, and a record kept of all wood, coal and water used from that time forth. The test was considered as commencing at the time the boiler made steam after the second fire was built.

At the end of the test, the coal weighed and unused was subtracted from the coal account—the coal unburnt in the furnace also being returned to that account—the ashes and unburnt coal being weighed dry as soon as possible after drawing.

The wood used was found about the Exhibition building, and its value as combustible taken as 0·3 of its weight. The steam from the boiler was blown into the atmosphere through a safety valve on the main steam-pipe, and the smoke-stack was furnished with a steam jet. A record was kept of the position of damper, the blower, firing, etc.

The height of water in the gauge-glass was noted at the beginning of test, was kept as nearly as possible at that point during the test, and at the end was brought exactly to it.



THE KINGSLEY BOILER.

Grate surface, 4 feet 6 inches by 2 feet 8 inches—12 square feet.
Heating surface, water on one side, 592·03 square feet.
Heating surface, steam on one side, 52·97 square feet.
Total heating surface, 645·00 square feet.

Ratio of grate to heating surface, 1 to 53·95.
Height of stack from grate-bars, 47 feet.
Diameter of stack, 24 inches.

The coal used was bituminous (Powelton steamship coal), and contained some moisture. A quantity was spread over a boiler and dried, the amount of moisture determined, and allowance made for the same. The coal was weighed in barrels on platform scales, from which it was dumped into a separate box, and used as occasion required.

The water was contained in two tanks, each on a scale, the suction of the feed-pump being arranged to draw alternately from each tank. These were weighed full and empty, and the difference taken as the weight of water used from each. The tank scales were very close to the boiler. The feed-water was heated by a steam jet, the weight being taken after the jet was turned off. The surface evaporation from the tanks was determined, and deducted from the total weight of water used.

No allowance was made for loss of heat in feed-water between tanks and boiler.

The temperatures of the feed-water, steam, smoke-stack, atmosphere, and the readings of the steam-gauge and chimney-draft were taken at short intervals, and the means calculated.

The draft in stack was obtained by means of a glass U-tube half full of water, one leg being connected with the inside of the stack, and the other with the atmosphere.

The temperatures of the steam and stack were taken from thermometers immersed in oil, which was contained in wrought-iron pipes leading into the steam-drum and stack—the steam-thermometer standing vertically, and the thermometer in stack at about 60° from the horizontal.

The height of the barometer was obtained from the United States Signal Office in Philadelphia.

The quality of the steam was determined by a barrel calorimeter. Steam was led by a well-felted pipe to a wooden barrel partly filled with water, the weight and temperature of which were known—the resulting weight and temperature of the water were taken as well as the pressure by steam-gauge. The water was stirred during the operation by a propeller revolving in a barrel. The following formula was used:

$$x = \frac{w_1 g_1 - w g - S H_1}{S g_2 - S H_1}$$

x = weight of water in one pound of steam;
w = weight of cold water;
w_1 = weight of cold water and condensed steam;
g = heat units corresponding to temperature of cold water, counting from zero F.;
g_1 = heat units corresponding to temperature of mixture, counting from zero F.;
S = weight of steam condensed;
H_1 = total heat of steam at pressure in boiler from zero F.;
g_2 = sensible heat units corresponding to pressure of steam.

After the test, one short and one long tube, which are easily removed, were taken from the boiler and cut near their lower ends. The water poured from them was clear till near the bottom, when it became slightly muddy. In the bottom of the short tube, and for about three inches up its sides, was a thin scale (about $\frac{1}{64}$ inch). The scale in the long tube was similar, with the addition of some fine granules; otherwise, the tubes were perfectly clean. The boiler had been running for about seven weeks.

TEST OF NOVEMBER 6, 1885.

Fire drawn at 8·22 A. M. New fire started at 8·26 A. M.

Steam forming at 8·32 A. M.

Test ended, 6·22 P. M.

Duration, 9 hours 50 minutes.

To change one pound of water at 166·79° to steam at 307·71° requires 1206·96 — 167·22 = 1039·74 units of heat, and as it takes 965·7 units of heat to change one pound of water at 212° to steam at 212°, one pound of water at 307·71° will require as much heat as 1·0767 pounds from and at 212°.

Pounds of wood used during test,	70·00
Pounds of coal used during test,	2205·29
Ashes,	196·50
Combustible—from coal,	2008·79
Combustible—from wood,	21·00
Combustible—total,	2029·79
Pounds of water evaporated under the conditions,	20423·50
Pounds of water evaporated from and at 212°,	21989·98
Pounds of water evaporated per hour under the conditions,	2076·96
Pounds of water evaporated per hour from and at 212°,	2236·89
Pounds of coal used per hour,	224·27

Pounds of coal used per hour per square foot of grate,	18·69
Pounds of water evaporated per pound of coal, under the conditions,	9·261
Pounds of water evaporated per pound of coal, from and at 212°,	9·971
Pounds of water evaporated per pound of combustible, under the conditions,	10·061
Pounds of water evaporated per pound of combustible, from and at 212°,	10·834
Mean temperature of feed-water,	166·79°
Mean temperature of steam,	307·71°
Mean temperature of smoke-stack,	227·13°
Mean temperature of atmosphere,	70·90°
Mean pressure of steam,	68·59
Mean barometer,	30·12 inches.
Mean chimney draft in inches of water,	0·33
Mean position of damper,	0·83 open.

Blower in use about two hours. Weather cloudy.

QUALITY OF STEAM.

8·45 A. M., steam contains 0·8 per cent. water.
10·45 A. M., steam contains 1·4 per cent. water.
12· M., steam dry.
1· P. M., steam superheated 7·06°.
2· P. M., steam contains 5·9 per cent. water.
3· P. M., steam superheated 20·85°.
4· P. M., steam contains 1·0 per cent. water.
5· P. M., steam superheated 40·28°.
6· P. M., steam superheated 3·97°.

TEST OF NOVEMBER 7, 1885.

Fire drawn at 8.14 A. M. New fire started at 8·19 A. M. Steam forming at 8·20 A. M. Furnace front cracked at 11·20 A. M. Test ended at 6·25 P. M.

Duration, 10 hours 5 minutes.

To change one pound of water at 164·39° to steam at 309·71° requires 1207·56 — 164·80 = 1042·76 units of heat. As it takes 965·7 units to change one pound of water at 212° to steam at 212°, one pound of water at 309·71° will take as much heat as 1·0798 pounds from and at 212°.

Maker's rating of boiler,	90 HP.
Pounds of wood used during test,	76·5
Pounds of coal used during test,	2985·25
Pounds of ashes,	305·13
Pounds of combustible used—from coal,	2680·12

Pounds of combustible used—from wood, . . .	22·95
Pounds of combustible used, total, ...	2703·07
Pounds of water evaporated, ...	25915·37
Pounds of water evaporated from and at 212°, .	27983·42
Pounds of water evaporated per hour under the conditions, ...	2570·10
Pounds of water evaporated per hour from and at 212°, ...	2775·24
Pounds of coal used per hour, ...	296·06
Pounds of coal per hour per square foot of grate,	24·67
HP. of boiler (basis of thirty pounds evaporation per hour from and at 212°, ...	92·51
Pounds of water evaporated per pound of coal under the conditions, ...	8·681
Pounds of water evaporated per pound of coal from and at 212°, ...	9·374
Pounds of water evaporated per pound of combustible under the conditions, ...	9·587
Pounds of water evaporated per pound of combustible from and at 212°), ...	10·352
Mean temperature of feed-water, ...	164·39°
Mean temperature of steam, ...	309·71°
Mean temperature of smoke-stack, ...	281·04°
Mean temperature of atmosphere,.	73·40°
Mean pressure steam, lbs., ...	69·40
Mean barometer, inches, ...	30·06
Mean chimney draft in inches of water, . . .	·66

Blower in use throughout the test. Weather cloudy, with rain for two hours. Damper wide open throughout test. Feed-water muddy.

QUALITY OF STEAM.

9· A. M., steam contains 2·8 per cent. water.
10· A. M., steam superheated 17·07°.
11· A. M., steam contains 8·4 per cent. water.
12· M., steam contains 7·8 per cent. water.
1· P. M., steam contains 2·4 per cent. water.
2· P. M., steam contains 4·3 per cent. water.
3· P. M., steam contains 1·9 per cent. water.
4·15 P. M., steam superheated 202·83°.
5·15 P. M., steam contains 2·4 per cent. water.
6·15 P. M., steam contains 0·6 per cent. water.

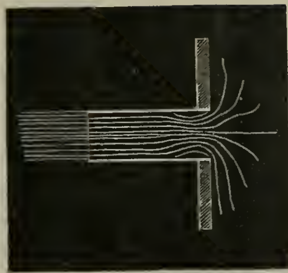
The sub-committee recommends the award of a SILVER MEDAL *with further reference to the Committee on Science and the Arts of the* FRANKLIN INSTITUTE.

(*To be continued.*)

ERRATUM, OCTOBER, 1886.

FRIZELL. COEFFICIENT OF EFFLUX, ETC.

The engraving, page 287, is placed to represent the pipe as vertical. It should be so placed as to represent the pipe horizontal as shown. The accompanying impression may be pasted over that in the JOURNAL.



FOR THE PROMOTION OF THE MECHANIC ARTS.

VOL. CXXII. NOVEMBER, 1886. No. 5.

THE FRANKLIN INSTITUTE is not responsible for the statements and opinions advanced by contributors to the JOURNAL.

FLOW OF METALS IN THE DRAWING-PROCESS.

BY OBERLIN SMITH.

[*A Lecture delivered before the* FRANKLIN INSTITUTE, *January 29, 1886.*]

LADIES AND GENTLEMEN:—In introducing the subject upon which I have been asked to address you this evening, "The Flow of Sheet-Metals in the Drawing-Process," I will refer briefly to *flowing*, in general, and to this motion as it occurs in various metallic and other solid materials. Webster defines "flowing" as moving "with a continual change of place among the particles or parts, etc., as in a liquid," and to many people the idea is connected only with liquids and other fluids. A further flow of the brain molecules which are supposed to represent their inner consciousness, however, will soon show them that such motion is a very common phenomenon in all the events transpiring in daily life before their eyes, both in semi-fluids and in solids; also, that this flow may be *elastic* or *non-elastic.*

Common instances of elastic flow may be found in the wonderful stretching of a piece of india-rubber to perhaps ten times its normal length, and its indignant return to exactly its original form;

HP. of boiler (basis of thirty pounds evaporation per hour from and at 212°, ...	92·51
Pounds of water evaporated per pound of coal under the conditions.	8·681
Pounds of water evaporated per pound of coal from and at 212°, ...	9·374
Pounds of water evaporated per pound of combustible under the conditions, ...	9·587
Pounds of water evaporated per pound of combustible from and at 212°), ...	10·352
Mean temperature of feed-water, ...	164·39°
Mean temperature of steam, ...	309·71°
Mean temperature of smoke-stack, ...	281·04°
Mean temperature of atmosphere,.	73·40°
Mean pressure steam, lbs., ...	69·40
Mean barometer, inches, ...	30·06
Mean chimney draft in inches of water, . . .	·66

Blower in use throughout the test. Weather cloudy, with rain for two hours. Damper wide open throughout test. Feed-water muddy.

QUALITY OF STEAM.

9· A. M., steam contains 2·8 per cent. water.
10· A. M., steam superheated 17·07°.
11· A. M., steam contains 8·4 per cent. water.
12· M., steam contains 7·8 per cent. water.
1· P. M., steam contains 2·4 per cent. water.
2· P. M., steam contains 4·3 per cent. water.
3· P. M., steam contains 1·9 per cent. water.
4·15 P. M., steam superheated 202·83°.
5·15 P. M., steam contains 2·4 per cent. water.
6·15 P. M., steam contains 0·6 per cent. water.

The sub-committee recommends the award of a SILVER MEDAL *with further reference to the Committee on Science and the Arts of the* FRANKLIN INSTITUTE.

(*To be continued.*)

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FLOW OF METALS IN THE DRAWING-PROCESS.

BY OBERLIN SMITH.

[*A Lecture delivered before the* FRANKLIN INSTITUTE, *January 29, 1886.*]

LADIES AND GENTLEMEN:—In introducing the subject upon which I have been asked to address you this evening, "The Flow of Sheet-Metals in the Drawing-Process," I will refer briefly to *flowing*, in general, and to this motion as it occurs in various metallic and other solid materials. Webster defines "flowing" as moving "with a continual change of place among the particles or parts, etc., as in a liquid," and to many people the idea is connected only with liquids and other fluids. A further flow of the brain molecules which are supposed to represent their inner consciousness, however, will soon show them that such motion is a very common phenomenon in all the events transpiring in daily life before their eyes, both in semi-fluids and in solids; also, that this flow may be *elastic* or *non-elastic*.

Common instances of elastic flow may be found in the wonderful stretching of a piece of india-rubber to perhaps ten times its normal length, and its indignant return to exactly its original form;

or in the bending or twisting of any wooden or metallic springs, etc., etc.

Instances of non-elastic flow are observed most frequently perhaps in connection with semi-solids, such as the clay upon the potter's wheel, the dough in the hands of the house-wife, or the putty under the glazier's knife. In the apparently rigid solids, such action is not popularly conceivable, but a little observation will show that the cold-forging of a piece of iron, or, indeed, any bending or other permanent distortion of any piece of metal, could not occur without this flowing of its molecules among themselves. Such flowing is shown on the grandest scale known to our present experience (whatever may have happened in the mighty work-shops of geological science) in the glaciers of the Alps, where great masses of solid ice flow slowly down their confining channels, changing their shape of cross-section as needs be, without being crushed or suffering any disintegration of their substance. This has been well described by Professor Tyndall, and it is, if I remember rightly, the same distinguished prowler about Nature's portals who tried the very interesting experiments regarding the flow of foreign objects through solid pitch, without leaving any holes in it. I could not find the description of this experiment, the other day, in any books that I had at hand, but I believe it was as follows: A number of stones were placed upon the top of, and a number of corks underneath, a mass of pitch several inches thick, and abandoned to their fate. After several months of silent disappearance, the corks arrived at the top and the stones at the bottom of the pitch, having floated and sunk respectively to their natural destinations.

In looking for the flow of solids in the metallic arts, it will be well to omit all *hot* processes as dealing with semi-fluids; but familiar examples of cold flow may be seen in wire-drawing, tube-drawing, cold-rolling and hammering, lead-pipe making, sheet metal-spinning, etc.

The first two mentioned are obviously analogous, about the only difference being that the tube is hollow (usually with a mandrel inside of it), while the wire is solid. Very similar to these operations, as respects the direction of flow of the particles of metal, is the reducing of a rod in grooved rolls, the chief difference being that the metal is coaxed along by friction, so to speak,

instead of being pulled by its finished end. In hammering a bar, the tensile stresses are entirely omitted and the action is wholly compressive, in a lateral direction, of course.

In lead-pipe making we have also an entirely compressive action, but one very different from that in the last-named process. Here the lead is *squirted* out, as it were, much after the manner of a syringe, or a sausage-stuffer, or one of those curious, but really excellent, squirting brick machines, the only thing about which I could not understand being that it should figure (if I remember aright) as a *mechanical* novelty at the "Centennial," and an *electrical* novelty at a certain well-known exposition of later date.

In the spinning process, there is a great variety in the method of flow, as the shapes produced from a flat disc (though sometimes from a tube or cup) are of many kinds, and the metal is, by the action of the burnisher, stretched in some places and forced into a smaller diameter in others. This process, by the way, is a tedious and expensive one, and requires a treatise to properly describe it in all its variations. Happily, it is much less practised than formerly, and is for many purposes being superseded by the very much quicker, cheaper and more uniform drawing-process and its modifications. Spinning is, however, often useful as a supplementary operation in finishing some shape which cannot be made in the dies. Part way in principle, between tube-drawing and the process referred to in our title, is such work as cartridge-drawing, where a "cup," made in a drawing press proper, is afterwards "broached" at several subsequent successive operations by being pushed through a female die that is a little too small for it. This is, in effect, the same as tube-drawing, the male-die, or "punch," acting as the mandrel. The only difference is that the tube is comparatively short, and has an *end* in it. The end is usually, in the case of cartridge shells, left thicker than the sides. This is not, however, necessarily the case, as the proportional thickness of the sides depends upon the space between the punch and die relatively to the original thickness of the sheet-metal.

Coming nearer to the process which forms our subject proper to-night, we find that its immediate predecessor as a cheap substitute for spinning was the "stamping process." I have no correct data regarding its history, but its practice does not to much extent reach back into the last century. Its object was chiefly the

production of seamless utensils from tin-plate, sheet-iron, brass, zinc, etc. These comprised such articles, as pie- and jelly-plates, milk-pans, dish-pans, dippers, cups, shallow sauce-pans, wash-bowls, colanders, wash-boiler bottoms and other articles of approximately conical and hemispherical forms. A general idea of such work in its finished state is given by the pictures, which Mr. Hiltebrand will now kindly throw upon the screen. As will be seen,

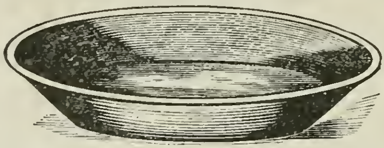

FIG. 1.

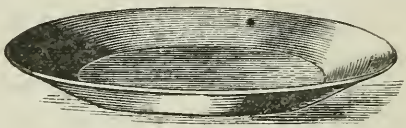

FIG. 2.

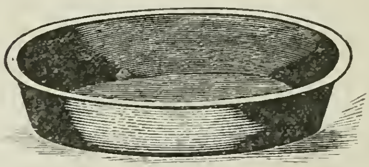

FIG 3.

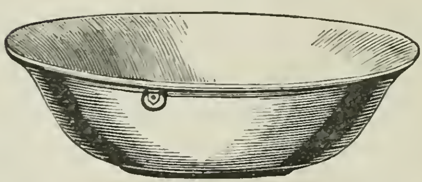

FIG. 4.

Fig. 1 is a bake-pan, *2* a pie-plate, *3* a milk-pan, and *4* a wash-basin. *Fig. 5* is a tea-kettle, in which there are three drawn pieces, namely, the cover and the upper and lower sections of the body. *Fig. 6* is a dish-pan. *Fig. 7* is an oil-can, in which the spout and bottom are, of course, separate pieces. *Fig. 8* is a ladle, to which the handle is riveted afterwards. *Fig. 9* is the bottom or well of

an ordinary wash-boiler. *Fig. 10* shows a screw-nozzle and cap, such as is used upon fruit-jars, oil-cans and other utensils. These

FIG. 5.

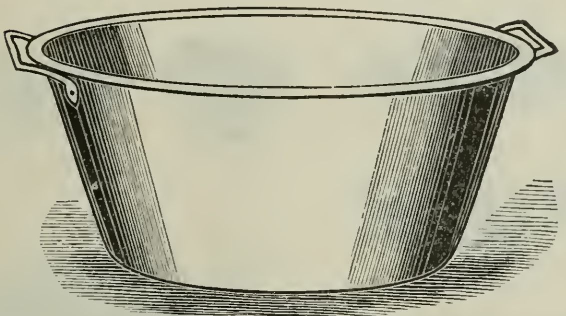

FIG. 6.

FIG. 8.

FIG. 7.

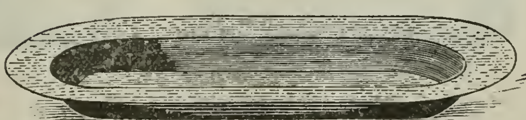

FIG. 9.

have the screw-thread automatically spun upon them after being drawn. *Fig. 11* is a tin-cup, and *12* an oval bake-pan. *Figs. 13*,

14, *16* and *17* are not properly drawn work, as the wrinkles have not been taken out, but only thrown into symmetrical forms, to answer as ornamental corrugations. *Fig. 15* is a shallow-plate,

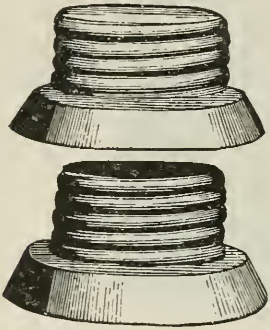

Fig. 10.

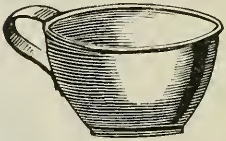

Fig. 11.

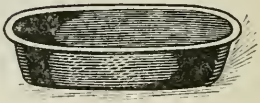

Fig. 12.

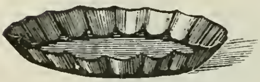

Fig. 13.

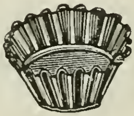

Fig. 16.

Fig. 17.

Fig. 14.

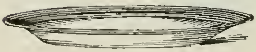

Fig. 15.

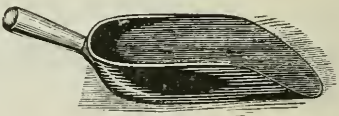

Fig. 18.

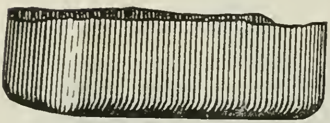

Fig. 19.

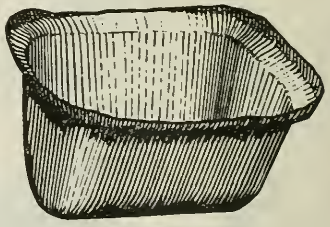

Fig. 20.

and *18* a dust-pan, to which, of course, the handle is attached afterwards. In *Fig. 19* is shown a rectangular box with rounded corners. In such work as this, the drawing-process proper applies only to the corners, and not to the straight sides, which obviously

have no flow of particles within them. These are simply bent up at right angles to the bottom, while in the corners, especially if of small curvature, the flow is very violent, making this one of the most difficult shapes to draw. In *Fig. 20* is shown a second operation, in which *Fig. 19* has been deepened and made smaller in diameter by a process, which will be explained further on. In

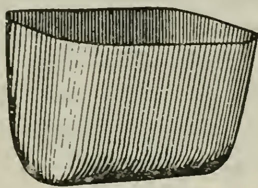

FIG. 21.

Fig. 21 is shown a third operation upon *Fig. 19*, where the flange has been turned up and trimmed. This turning up of the flange is not properly drawing, although the metal has to be upset, or crowded together. It is done by forcing the article down through a die, and can only be applied where the reduction in diameter is quite small, as otherwise the wrinkles would fold upon one another and the work be ruined. The article shown, as completed in *Fig. 21*, is intended for a seamless elevator bucket. In comparing *Figs. 13* to *17* with drawn work, and in describing the genesis of *Figs. 19* to *21*, I have digressed a little from "stamping" in order to explain these pictures while on the screen.

All the other work mentioned was usually done in a drop-press, although a crank-, lever- or screw-press could be employed, as far as the proper motion of the dies was concerned, had force enough been applied. The lower die was the female, or intaglio, and fitted the outside of the work before the wired or curled rim at the top was made; that is to say, the top of the die was a flat, smooth surface, extending some distance out, so that its outer diameter was fully as great as that of the blank. "Blank," it may be explained, is the technical name of the flat disc of sheet-metal which is to be formed to shape. The upper die was the cameo, technically the male-die, punch or "force," as in this process it was generally termed, and was usually made of an alloy of lead and tin which could be cast into the lower die while in the press, and thus a perfect fit be cheaply made. It had a flat flange, extending over

the flat top of the lower die, which served to mash the wrinkles out from the flange of the work—it being understood that the work is usually *hat*-shaped, with a flat projecting flange. This was afterwards wholly or partly trimmed off true, and was often curled over a wire ring, or else over the place where the wire ought to be—somewhat upon the principle of the Irishman's "empty bag with praties in it." This latter process is known as "false-wiring" or "curling." The appearance of either this or real "wiring" is shown at *Figs. 4, 11, 15*, etc. Now it is obvious that a flat disc formed into a concave die will wrinkle near its periphery on account of being there reduced in circumference. This principle is taken advantage of in making cake-pans and such work. See *Figs. 13, 14, 16* and *17*. Such shapes can easily be made perfect at one blow, because the corrugations are systemized wrinkles, of the proper amplitude to just take up the surplus metal. If the work must be smooth, the wrinkles can be mostly, but not wholly, mashed out by a heavy enough blow, *providing* the wrinkles are quite shallow, so that one cannot possibly fold over upon another. Of course, in so doing the metal must be "upset," or crowded together in a circumferential direction. In order that the wrinkles may be thus shallow, the work must be shallow relatively to its diameter, say as one to fifteen or twenty, in ordinary sizes of tinware, with a metal as thin as tin-plate, which averages perhaps only about one-sixty-fourth-inch thick. (It may be said, *en passant*, that with much thicker metals, *e. g.*, a piece of one-fourth-inch boiler plate made into a pie-dish, the metal is so braced within itself that it "upsets" to a great extent *before* the wrinkles form, and they are apt to be almost *nil.*) To make deep work by the stamping process, it became necessary to *coax* the metal down, so to speak, by several successive operations—sometimes as many as eight or ten. For these, the same "die" was used with several "forces," each one having its convex part projecting below its flat flange a little further than the last, say from one-half inch to one inch. This flange beat out the newly-formed "flange-wrinkles" at each operation, while the same thing was done for the "body wrinkles" (those in the conical surface) by the nearly touching sides of die and force. An incidental advantage about such soft-metal "forces" as we have been considering, besides their cheapness and facility for fitting, is their capacity for a ready internal

flow of their particles by the force of the press's blow, thus forging themselves to exact shape each time, in spite of their tendency to wear and mash out of shape. This is especially the case when they are used in a drop-press, where there is great force and rapidity of percussion at the extreme bottom of the stroke.

The *drawing-process* proper, which we are especially to consider to-night, and which will be more fully described further on, was designed as a substitute for stamping, and consists in confining the flange of the work between two parallel surfaces so tightly that wrinkles have *no room to form*, and its molecules consequently flow outward radially to compensate for what they must flow together circumferentially, as their diameter at any given place is reduced. Its products show deeper and better work in one operation than could be obtained in several successive ones by stamping. Curiously enough, the *name* of the last-mentioned process has been retained by many of the manufacturers who make nearly all their work by drawing, using only an occasional drop-press for auxiliary operations. It should be understood, then, that when we read in the newspapers of the "Great American Conglomerated Association for the Diffusion of Good Prices Among Stampers," or see the market quotations for "stamped ware," we must interpret the term in a commercial, and not in a technically mechanical, sense. It is now generally supposed to comprise all seamless sheet-metal household utensils, as deep as a pie-plate, or deeper. These are usually made of tin-plate (the best qualities of goods being re-tinned after being brought to shape) or else of sheet-iron or steel coated with tin or with some porcelain-like material, of which there are several excellent varieties in the market. This term "stamped" seems to have its chief individuality as in contradistinction to "pieced"-ware, which is soldered together in sections.

Of the *history* of the drawing-process I have not been able, in a somewhat casual search, to find any printed record, except an encyclopædic statement that it was first practised by a Mr. T. Griffiths, in 1841. Mr. Grosjean, of New York, who probably first used it in this country, and has been one of its largest users ever since, informs me that he thinks it was practised in France as much as fifty years ago, but cannot be sure of the date. I am indebted to my friend, Mr. F. G. Niedringhaus, of St. Louis, for some valuable information upon this subject. He tells me that the

"Prussian system" of metal-drawing was invented by the Strouvelle Brothers, at Saarlouis, Rhenish Prussia, and was practised by them there, and, later, at Ars, Alsace. From there skilled artisans introduced it into this country early in 1866, it being put into practical working shape by the Lalance & Grosjean Manufacturing Company, and a little later by the St. Louis Stamping Company. Soon after this, one Marchand, who had been employed by the first-named company, and had learned something of the process, made it prematurely public, and commenced to build presses adapted to its practice. These bore his name, and were for a time the only ones in the American market. As their maker has long been out of the business, and is, I believe, now dead, I do not feel that I am unduly advertising his wares by thus making him a factor in history. Since his time various improvements have been made in the details of the process, and in the strength and convenience of the presses used. Many of the minor improvements in the manipulation of the metal have been kept secret by their inventors, and are practised only in a few large factories.

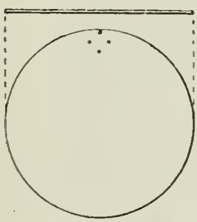

Fig. 23

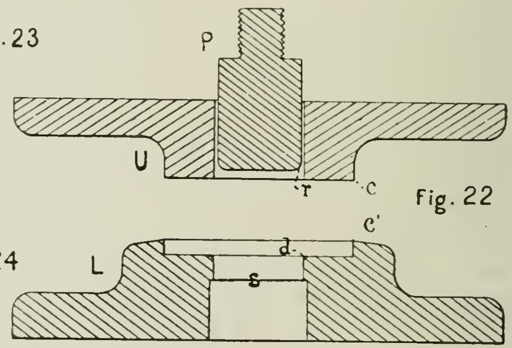

Fig. 22

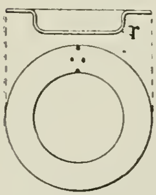

Fig. 24

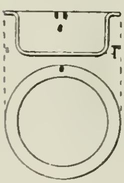

Fig. 25

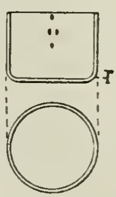

Fig. 26

Proceeding to describe in detail the process in question, we see upon the screen in *Fig. 22*, a vertical section through the axis of a

pair of drawing-dies for plain cylindrical work, *L* being the lower die, *U* the upper die (sometimes termed blank-holder), and *P* the punch. Such a die may both cut and form the work at one stroke, *c* being the male cutting edge and *c′* the female cutting edge, or it may be used for blanks already cut, which are merely thrown into the recess formed by *c′*, it acting as a guide to hold them central. When the operations of cutting and forming are thus combined, it is usually termed a "combination drawing-die," and this type is very generally used for all small work, say up to twelve inches in diameter, while for larger work, it is often the practice to cut the blanks separately and make the dies of a cheap material, like cast-iron, which would not answer for cutting edges. There can now be purchased in the market, circles of tin-plate, which are tinned in that form, thereby saving the wastage which occurs from having the scrap-metal left at the corners of the rectangular sheet, uselessly coated with tin. Where, however, such circles are not used, the tendency is, I think, more and more towards the use of combination-dies, so as to do the whole work in as few operations as possible. Whichever way the blank may have been cut, the operation is as follows: The die *U* descends until the blank is firmly held between the two flat surfaces, when *U* remains stationary until the punch *P*, which has so far descended with it, continues its descent, drawing the metal into a cylindrical form, as shown in *Fig. 26*, and stripping it from the punch against the stripping-corner *s*, when the latter rises to its original position. The slight expansion of the top edge of the cup by the elasticity of the metal, is usually sufficient to prevent it from pulling up into the die again, although sometimes trouble is experienced unless the corner *s* is kept very sharp and hard. It is usually necessary to "vent" the punch by a small hole, running up through it, not shown in the drawing, in order that the suction of the air cannot help to pull the cup upward. The rising to a normal position of the upper-die may occur at any time after the flange of the work has disappeared around and below the corner *d*, but this rising usually takes place at the last part of the stroke and simultaneously with the last part of the upward motion of *P*.

In *Fig. 23* is shown a section and top view of the blank before being drawn. In *Fig. 24* is the same as it appears when it has been drawn to about one-third of its depth, and in *Fig. 25*, when

about two-thirds. In *Fig. 26* is shown the completed cup, the flange having entirely disappeared. The direction in which the metal is forced to flow, is shown graphically by the four dots in the form of a square upon *Fig. 23*. In the subsequent figures, these dots will be seen to have assumed the form of a diamond, whose axis, lying in a radial line, continuously lengthens, while its other axis, lying in a tangent, is to about the same extent shortened, thus showing that the metal is stretched radially with its particles flowing away from each other, while circumferentially it is upsetting, and the particles are approaching.

The question naturally occurring to the uninitiated is, what is the limit of depth to which an article can be drawn from a flat sheet of metal? This depends upon a variety of circumstances, such as the kind and quality of metal, its thickness relatively to the size of the work, etc. A good quality of "one-cross" (I-X) tin-plate, which is about one-sixty-fourth-inch thick, can, in small articles, say under eight inches across, be drawn to a depth equal to about one-half of its diameter, although I have known frequent cases where this depth has reached two-thirds; for instance, a 3-inch box, 2 inches deep, etc. With soft brass and copper, a somewhat greater depth can be obtained, while with zinc, the proportional depth is considerably less. I have had but little experience in drawing gold and silver, but as far as I know, they act much in the same way as does brass.

A little study of the work which is being done in a die like this will show why a limit of depth is soon reached. The actual work consists, firstly, of molecular friction, or the causing to flow among themselves of the particles of metal in the flange before it turns the corner *d*; and secondly, in overcoming the friction between the upper and lower sides of the metal, and the flat surfaces of the dies. If we imagine the part of the work which has become cylindrical to be a series of little ropes (forming the elements of the cylinder), which are attached to the punch by running across under the bottom of it, and thence up its sides to the corner *d*, we will see that all the resistance offered in the flange is being overcome by the punch pulling these ropes downward over the corner *d*, it acting as a stationary pulley-block. Hence, if the united tensile strength of all these little ropes is great enough to overcome the resistance at its maximum, which is soon after the

metal begins to flow, when the flange is at its widest, perfect work will be the result. If, however, there are not enough ropes to do this work, which is the case when the diameter at *s* is too small, the flange will not start to move, but the punch will simply go down and tear the bottom out of the work. Thus, if we try for too great a depth relatively to the proposed diameter, the work will be spoiled, because this means a wide flange and more resistance.

It is evident that the little ropes spoken of will "render" more easily about a large corner than a small one, and that therefore a better result may be obtained by increasing the radius of the drawing-corner *d*. If, however, this is carried too far, a considerable part of the flat holding-surface of the lower die is lost, and a new

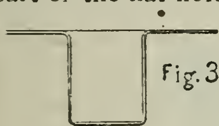

Fig. 31

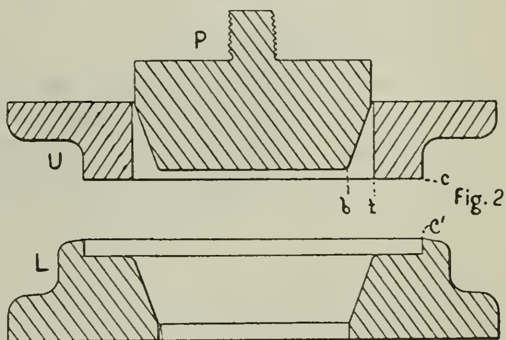

Fig. 27

Fig. 32

Fig. 28

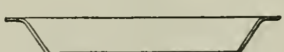

Fig. 29

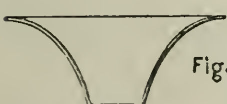

Fig. 33

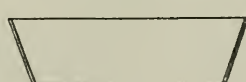

Fig. 30

evil arises, known as body-wrinkles, which will be explained further on. Practically, for working tin-plate, the radius of the corner *d* is made from one-eighth to one-quarter inch. The curvature of the corner *r* upon the punch also affects the result. If it is made perfectly sharp, it tends to cut the metal which is pulled around it, and practically ought not to be less than of one-sixteenth inch radius. It is often much larger than this to suit shape

of work desired, but if made very large, causes the trouble of body-wrinkles before referred to, on account of there being a certain zone of the blank which is unconfined by the flat holding-surfaces.

You will now see upon the screen, a new diagram, marked *Fig. 27*. This is a vertical axial section of a pair of conical drawing-dies, similar to the last shown, except that they produce conical instead of cylindrical work. They, like the others, may either be "combination," or may work blanks already cut. In *Fig. 28* is shown a section of a blank and in *Figs. 29* and *30*, successive stages of the work while being drawn. The radical difference between this and cylindrical work consists in the blank being unconfined over a certain space which lies between the lower face of the punch and the upper holding surface of lower die, and this is represented by the distance *b*, *t*, *Fig. 27*. When the drawing actually commences, the inner portions of the flange as they flow inward, enter this zone and constantly have to become smaller in circumference. Now as there are no holding-surfaces to prevent, wrinkles are formed which are carried down into the conical portion of the work and are known as "body-wrinkles," in contradistinction to the "flange-wrinkles" which sometimes occur when the upper die is not set down hard enough upon the lower. These are usually removed by roller-spinning. The same difficulty with regard to getting sufficient tensile strength of metal around the punch to pull down the flange as occurs in cylindrical work, appears in still greater force in conical, as the hypothetical little ropes spoken of are still fewer in number around the small circle bounded by *b* than they would be in the larger one bounded by *t*, were the punch cylindrical. It may be said generally, therefore, that any work with a small diameter of bottom in proportion to extreme diameter of flange is difficult to draw. This type is illustrated in *Figs. 31*, *32*, and *33*, which are the most troublesome of all shapes to deal with.

I have before shown that the resistance to be overcome consists of both molecular and surface friction. In drawing conical articles, such as bowls, pans, etc., which do not require absolute uniformity and accuracy, advantage is taken of this fact by drawing two or more together, sometimes even as many as four. In such a case, the surface-friction is no greater for four than for one,

while the molecular friction is four times as great. The sum of these frictions is, however, obviously less in proportion to the tensile strength of work surrounding the punch, which is as the number of thicknesses therein. There is, therefore, a great gain in strength, and much deeper work may be made than by drawing one at a time.

These several thicknesses can also be removed from the press and spun and trimmed all at a time, after which they easily drop apart. This method is only applicable to work with considerable taper. Obviously, it would not answer with cylindrical articles, as they could not be separated one from the other easily, and their difference in diameter would be too apparent.

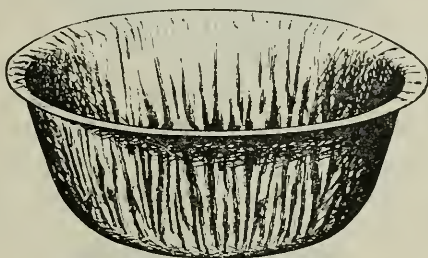

FIG. 34.

In *Fig. 34* is shown a photograph of a wash-basin just as it leaves the dies, where the body-wrinkles are very apparent, and where also the unevenness in contour of the flange plainly appears. This is caused by slight variations in the thickness and ductility of the metal, and also in the flatness of the holding-surfaces of the dies. As regards the latter, the variation from a perfect plane is partly caused by imperfect construction, but is in a greater degree due to their springing or bending out of flat by the unequal yielding of different parts of the press when the holding-pressure is brought upon it. Incidentally, it will be well to mention that the proper action of the drawing-surfaces depends not only upon their flatness, but upon extreme smoothness, and upon the grain of the polish of the metal being in a radial rather than in a circumferential direction. Referring again to body-wrinkles, I will mention that they may be partially avoided by an extra heavy pressure upon the flange, in which case the tensile strains upon the metal surrounding the punch tend to partly pull them out, as it were.

As upon the screen before you there happens to appear two photographs germain to the direction of the flow of particles from the flange to the body, I will here recur to the subject, explaining

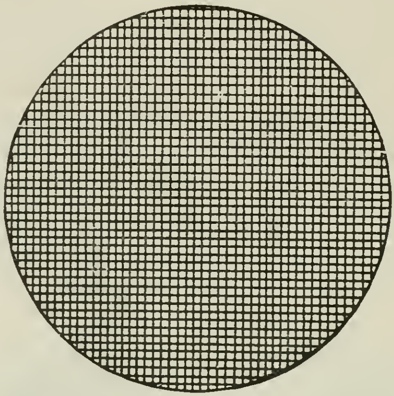

FIG. 35.

that *Fig. 35* is a blank cut from so-called "decorated tin," where a series of lines divide the surface into a number of small squares. The appearance of these squares after the metal has flowed to its

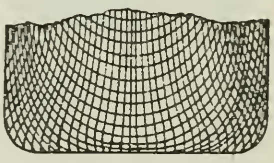

FIG. 36.

new shape is beautifully shown in *Fig. 36*, which is photographed direct from a piece of cylindrical work made from a blank like *Fig. 35*. This cup is shown in side view, and at the upper edge is seen the effect of uneven drawing incident especially to deep work. Such an edge needs trimming, but where the depth is not over about one-sixth of the diameter, it is usually good enough for commercial purposes without.

In *Fig. 37* is shown a pair of cylindrical "deepening" dies. They are in principle exactly like the plain dies, *Fig. 22*, except that instead of working a plain blank, they receive a cup which has been previously drawn at a first operation. Such a cup is shown in *Fig. 38*. It is placed within a recess in the lower die, which guides it exactly to place. The upper die is made of such a diameter as to ex-

actly fit inside of it, and the rounded corners upon both dies and punch, as shown at *r*, *r* and *r′*, *r′*, are made of such a curvature as to fit the work at the points marked by the same letters. Successive stages of this work, while being drawn deeper at this operation, are shown at *Figs. 39* and *40*, while at *Fig. 41* it is shown com-

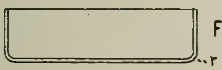

Fig 38

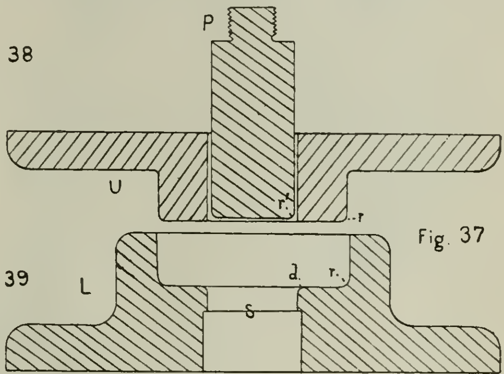

Fig. 37

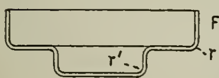

Fig. 39

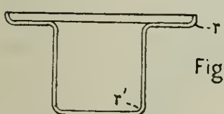

Fig. 40

Fig. 41

pleted, as dropped through the die *L*. This process is known as "deepening," and can obviously be carried on in successive operations without limit, provided the metal does not harden, or can be annealed between operations. Thus, with brass, copper, black-iron and steel, etc., long tubes may be drawn from a flat sheet, as is instanced in some of the operations of cartridge-drawing, etc., these metals allowing the necessary annealing to be performed. With tin-plate, however, the coating of which would be spoiled by annealing, not more than two operations can usually be performed. With such material, a box may be obtained of a depth about equal to its own diameter, but not much deeper, and in such a case, the metal is made very brittle.

There are not many data available regarding the pressure per square inch for holding various kinds of metal between the surfaces of drawing-dies. I hope at some future time to make a systematic course of experiments, but so far have the records of only a few

informal ones. One of these showed that it took 4,600 pounds to hold without wrinkling the flange of a $5\frac{3}{4}$ x $1\frac{5}{8}$-inch milk-pan. This had about twenty-three square inches of drawing-surface, and therefore required about 200 pounds per square inch. Another case was that of a small seamless blacking-box with two and one-half square inches of drawing-surface, where a pressure of 800 pounds was applied, making it 320 per square inch. In a third case, a $1\frac{9}{16}$ x $\frac{3}{8}$-inch box had 1·35 inches of drawing-surface, and took 648 pounds pressure, being 480 pounds per square inch. This stood over 4,000 pounds, however, without breaking, showing for such shallow work a great excess of drawing capacity. It will be seen that the average of the above experiments is something over 400 pounds per square inch; the average pressure really necessary, however, will probably run somewhere between 200 and 400 pounds.

Regarding the maximum limit of speed in drawing, there is the same lack of data based upon systematic experiments. The presses in use, run from say ten strokes per minute in the larger sizes, to 200 in the smallest. This gives a maximum punch speed (counting on twenty inches in the former case and one in the latter) of about fifty feet per minute. At this rate, the metals used seem to flow properly without tearing, though probably in some cases a slower speed would be better. Iron, I believe, will flow faster than brass, but how much beyond the above speed it is practicable to go, must be left to the verdict of some future very interesting experiments.

In *Fig. 42*, now upon the screen, you will see a perspective view of an ordinary type of drawing-press, such as is usually employed for small work, say not over ten or twelve inches in diameter. In this the dies are shown set, the upper die at *U* and the lower at *L*. The "outer-slide-bar," carrying the upper die, is pushed downward until the latter is in contact with the blank, by means of cams upon the main-shaft, working against rollers in the slide-bar. These cams have a cylindrical portion of their surface so arranged as to hold the upper die perfectly still during the latter half of the descent of the punch and the first half of its upward return. The punch is attached to the "inner-slide-bar," which is driven by a crank and pitman in the usual way. Such presses are arranged with accurate adjustments for giving the proper pressure upon the

blanks and for making the punch descend to exactly the proper point. The outer-slide-bar is raised, in this case, by springs, which

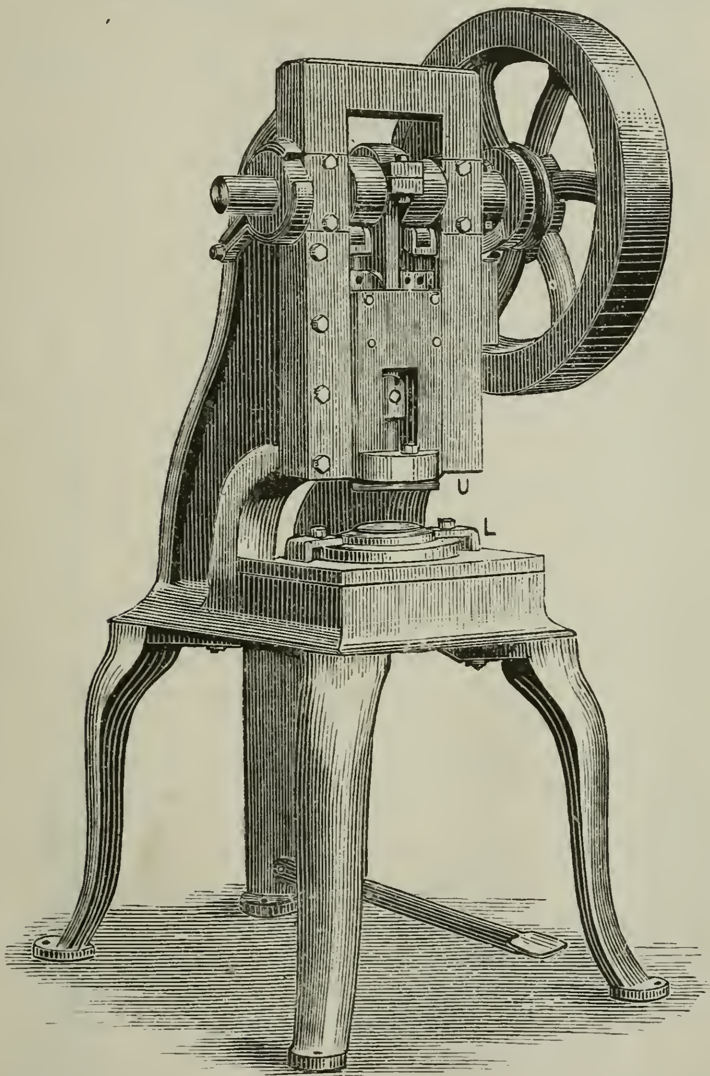

Fig. 42.

do not show in the picture. Sometimes "return" cams are used for this lifting. This view, *Fig. 42*, shows a press made in England. In *Fig. 43* is shown a much larger drawing-press, made in

Germany. For obvious reasons, of a non-advertising nature, I have not shown views of any American presses, although some of them are of much better design than these before you. It may be said, however, in favor of the German presses, that they are usually fitted with more conveniences than are those made in this country, in the way of extensive and rapid adjustments, which adapt them to a great variety of shapes and sizes of dies. In this particular point we may well copy the Germans, who, perhaps, have arrived at a greater state of perfection than we, on account of having been longer at the business. The machine represented in *Fig. 43* differs from the smaller one shown, and from many large ones in the market, by having the bed which carries the lower die to slide upward to meet the upper die, which is stationary. One advantage of this "bottom-slide" construction is that said bed, which is very heavy, can be returned to position by gravity, without any lifting arrangements, actuated either by cams, weighted levers, springs or steam-cylinders—all of which methods are used in "top-slide" presses. Another advantage is that the slide working the punch need only move through a distance necessary for doing its actual work, while with the other plan it must move this distance *plus* the waste space through which the blank-holder moves until the work is held—this space being necessary for removing conical and flanged work that cannot drop through lower die. This wastes a good deal of its stroke, and necessitates a much greater radius of crank, with the accompanying increased strength in shaft and gearing. Before leaving the subject of presses, I want to call attention to a fact which even yet is not fully realized by drawing-press makers, and that is, the immense importance of making the bed and the outer-slide, which carries the drawing-dies, of enormous *depth* relatively to their width. These members are really beams, usually supported at their ends, with the greatest working pressure occurring in the middle. It is very necessary that these beams should not bend to any appreciable degree, and therefore their depth must be great. A press otherwise abundantly strong enough, will utterly fail to make good work if these cross-members are allowed to spring so as to throw the face of the dies out of true when the pressure is brought upon them. In such cases, flange-wrinkles will commence to form in certain parts where the holding-surfaces happen to recede from each

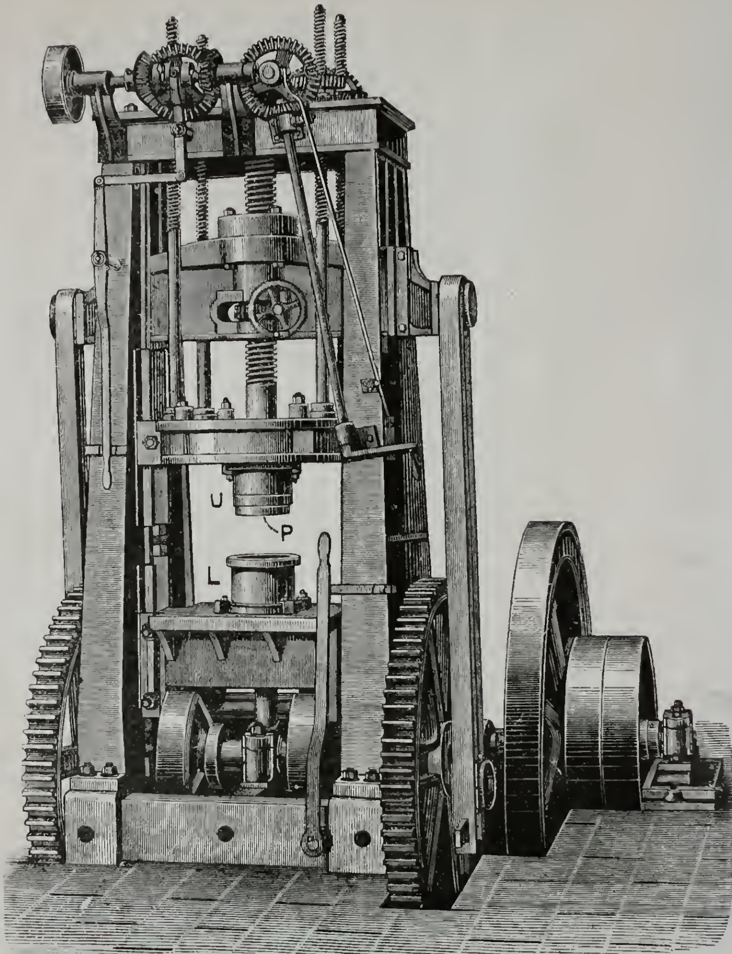

FIG. 43. GERMAN PRESS.

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other; and, when once formed, cannot possibly be removed. Worse than this, these wrinkles tend to force the dies still further apart and throw them into undulations of "springiness," so to speak, which is apt to entirely spoil the work.

While on the subject of presses, it may be well to mention a sort of mongrel drawing-press that is used for small work in some brass factories; where the outer-slide is driven by *cranks* instead of *cams*. This gives a simpler construction, but fails to properly "hold" the blank—except for an instant when the crank is passing its dead-centre. In the best modern practice such presses are giving way to those of the type shown in *Fig. 42*.

Recurring again to dies, I will mention that a certain method is frequently practised for drawing small articles, which are comparatively shallow, in an ordinary single-action press. This consists in using a strong spring-pressure for holding the flange of the metal from wrinkling. The dies used are generally constructed with a holding-ring surrounding the punch, and within the female cutting-die, which is pushed up by heavy springs, and answers as the lower holding-surface. The punch and female cutting-ring are fast in the lower die, while the upper die is the male cutting-die, with a recess in it, which does duty as the female forming-die. The flat lower face of this is the upper holding-surface. These are known as "spring drawing-dies," and answer a very good purpose, when small enough to make the power which they waste of little practical account.

It will naturally occur to the student of this subject that some easy method is desirable for determining the diameter of the blank for any given piece of drawn work, especially if its dies are to cut; as cutting edges are expensive to make—and to *alter* if guessed at and made wrong at first. Aside from lucky guessing, somewhat guided, perhaps by analogies from other approximately similar work that dies have been made for before, I have in my own practice used three principal methods to obtain this measurement of blank diameter.

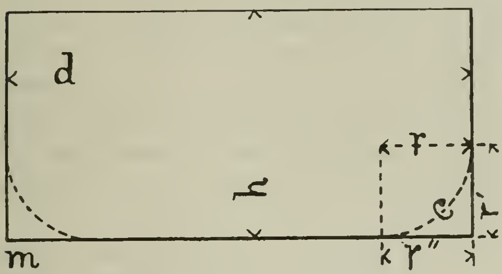
The first of these methods is the *tentative* one. It is the surest, but, in many cases, the most expensive. It consists in cutting blanks of as near as possible the right size and shape by guess, and trying them successively, modifying the shape of each to suit circumstances, until the proper shape of drawn work is produced.

For dies that do not cut, this isn't difficult, as the flat holding-surfaces can be made plenty large enough, and whatever gauging arrangements are to guide the blank, can be put on afterwards when its correct proportions are decided upon. In cutting dies, the female cutting-ring must be made separately, and left unfinished until the size and shape is ascertained. The male cutting-ring, which forms part of the upper holding-surface, must of course be made, but can be left plenty large enough until this trial has been completed.

The second method referred to, may be called the *gravitative*. It depends for its accuracy upon the principle, that the thickness of the metal in a piece of drawn work, is the same as it was in the original blank, which is in fact usually the case. My own method is to carefully weigh the sample piece of drawn work which is to be reproduced, and then, knowing the weight of one square inch of a piece of similar sheet-metal of exactly the same measured thickness, to calculate the number of square inches necessary in the blank and make its diameter to suit this given area. This method can obviously be practised only where a sample of the work is at hand, and where the blanks are circular in form. Certain inaccuracies may arise in the practise of this method, where there are sundry beads, corrugations, etc., near the centre of the piece of drawn work, which tend to let the metal stretch when the punch comes home in the die. Such action is properly embossing, rather than drawing, and stretches the metal thinner in certain places, which of course invalidates the accuracy of this system. It is, however, often useful for work whose contour is simple in form, near the central portions, where a drawing action does not take place.

The third method spoken of may be called the *mensurative*. This, too, depends upon equal areas and upon the thickness of the metal remaining the same. In the case of plain cylindrical work, a very simple formula, which I have worked out for the purpose, may be used. This is given in *Fig. 44*, equation III, for a box or cup whose corner at m is sharp, or nearly so, and in equation VI, for a round-cornered box. The latter formula is not theoretically accurate as regards equal areas, but serves an excellent practical purpose where the corner is not of too large a curvature—say with a radius not more than one-fourth the depth of the cup. The

FIG. 44.



Let, (in inches.)
d = Diam. of cup.
h = Height of cup.
r = Radius of corner.
c = Arc of 90°, with radius r.
a = Area bottom + sides
a = Area blank, also.
x = Diam. blank is to be cut.

$$a = \cdot 785\, d^2 + \pi dh., \qquad (1.)$$

$$x = \sqrt{\frac{a}{\cdot 785}} = \sqrt{\frac{\cdot 785\, d^2 + \pi dh.,}{\cdot 785}} \qquad (2.)$$

$$x = \sqrt{d^2 + 4dh}, \text{ for sharp-cornered cup,} \qquad (3.)$$

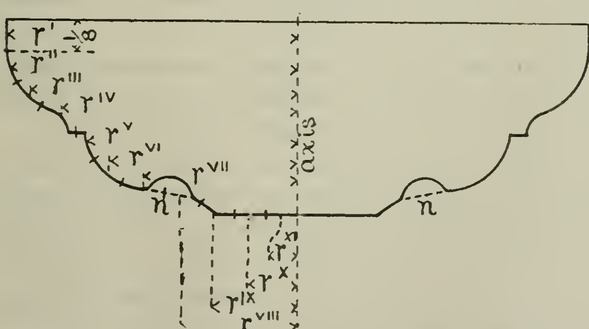
$$r' + r'' - c = \frac{r}{2} - \qquad (4.)$$

$$2 = (r' + r'') - 2c = r - \qquad (5.)$$

$$x = \left(\sqrt{d^2 + 4dh}\right) - r, \text{ about, for round-cornered cup; with small corner, say where } r < \frac{h}{4} \qquad (6.)$$

diagram given in *Fig. 44* is a vertical axial section of a cylindrical box or cup, the same as was shown in *Fig. 26*. It is not worth while here to give the working-out of the formulæ, as by a close inspection, the figures will explain themselves.

FIG. 45.



Let (in inches.)
r^{i}, r^{ii}, r^{iii}, r^{iv}, etc. = Radii drawn to axis from centres-of-gravity of ⅛ inch segments of contour line.
$s = r^{i} + r^{ii} + r^{iii} + r^{iv}$, etc.; that is, the sum of the radii.
a = Area bottom + sides.
a = Area blank, also.
a^1 = Area of one zone whose average radius is r^{i}, r^{ii}, r^{iii}, etc.
x = Diam. blank is to be cut.

$$a' = 2\, r^1 \pi \tfrac{1}{8}, \qquad (1.)$$

$$a = 2\, s\, \pi \tfrac{1}{8} = \cdot 785\, s, \qquad (2.)$$

$$x = \sqrt{\frac{a}{\cdot 785}} = \sqrt{\frac{\cdot 785 s}{\cdot 785}} = \sqrt{s} \qquad (3.)$$

In *Fig. 45* is shown a method which I have devised for ascertaining the area of a piece of drawn work of irregular contour as regards its vertical section. This method is a graphic one, an exact profile of the work being drawn to scale of real size, and this contour-line being laid off, from its axis outward, into sections each exactly one-eighth inch long. From the centres of these sections, at the points marked r', r'', r''', etc., horizontal measurements are taken to the axis. These measurements, of course, represent various radii of the piece of drawn work in question. If we let the sum of them be called s, we then get the very simple formula given in equation III. The reason that just one-eighth of an inch was taken for the length of these segments of the contour-line was that it happened to reduce the equation to the simple form given, while any other length would have made it more complicated. The principle here involved is, obviously, that of the area of any zone being its width, multiplied by its circumference at a point representing the centre of gravity of its single cross-section. The points marked r', r'', etc., are, of course, not accurately in the centre of gravity of each of the little segments, but they are practically near enough so. The same principle occurs in this method as in the last-mentioned one regarding places in the metal which will stretch thinner when formed to shape, like deep beads, or other indentations. This trouble may be mostly neutralized, however, by bridging over them, so to speak, in making the contour-line; that is, by running the latter across from point to point of the corrugations instead of following their curves, wherever it is judged that stretching will take place. This amended contour is shown at n, n, *Fig. 45*, by dotted lines, and on it the segments should be laid out.

In making drawn work whose top view is elliptical, instead of round, the formulæ above given may be used with some modifications. To do this, the ellipse is treated separately, as regards its short and long axes, and values are inserted in the two equations which would be used for circles which approximately coincide with the sides and ends of the ellipse, at the terminii of its respective axes.

In making rectangular work with round corners, some idea of the shape of the blank may be obtained by treating the corners as belonging to a circle of the proper diameter, while the sides of

the rectangle (which properly are not drawn at all, but only bent to shape), may be treated nearly by actual measurement, as in them very little stretching takes place. As regards the corners, however, the tentative method is the safest wherever it is possible to use it.

It may be of interest to state that certain kinds of work are drawn from whole sheets of metal, wherever such sheets are only a little larger than the blank which would otherwise be used, and the cutting to shape is done in a pair of "trimming"-dies afterward. This method is frequently used for such work as wash-boiler bottoms, dust-pans, halves of toy animals, etc, and gives an accuracy of edge contour not attainable the other way.

As an accessory to the process of drawing, the old-fashioned process of spinning is sometimes used, for finishing certain details of shape which cannot be done in the dies. The drop-press is also occasionally brought into requisition for finishing certain shapes. Much more common than either of these, however, is the process of roller-spinning before referred to. This is very much more rapid than the old-fashioned hand-spinning with a burnisher, and is done very quickly by a cheap quality of labor. It is used for crushing out such body-wrinkles as were shown you in *Fig. 34;* in wash-bowls, conical pans and such work. One or more of these articles are placed upon a steel chuck, without even stopping its revolution, and being pushed up solidly by a loose pad upon the dead-spindle of the lathe, so that they are driven by the friction of the chuck, a hardened steel roller, mounted upon a slide rest is rapidly passed once over them, under considerable pressure, and thus the wrinkles are entirely removed.

On the table before me, you will see a large number of specimens of drawn work of various proportions and of several materials. These I shall be glad to show in detail to anyone interested, after the lecture is over. The larger articles on my right were kindly loaned me by Mr. George Melloy, of this city, and very well represent the general line of commercial stamped-ware hinted at in *Figs. 1* to *18*. Perhaps the most interesting among them is this milk-can, the lower part of which is drawn seamless in one piece. It is about a foot in diameter by nearly two feet deep, and was drawn and deepened at three or four operations with annealings between and the tinning afterward.

With regard to the future possibilities of this interesting process of drawing metals, we probably can form but a primitive idea. Already, articles as large as soda-water fountains and the halves of kitchen-boilers are drawn from a flat sheet; and it would be simply a matter of first cost for plant, to draw large steam-boilers in the same way. There would certainly be no real difficulties, except the expense of plant, in drawing such things as bath-tubs, boats of small sizes, etc., by precisely similar methods to those I have indicated this evening.

Of the real value of this invention, I think the public have a very inadequate idea—perhaps because there is so little generally known about it, the practise of the art being mostly confined to a few large and very secretive-minded factories. To it mainly, however, we owe the wonderful cheapness, abundance and variety of the household utensils, which help in some degree to lighten the burdens of toiling millions of wives and mothers the world around. If, like Abou-Ben-Ahdem, the man who makes to grow two blades of grass where grew one before, is a lover of his fellow-men, with what laurels shall we crown the brow of him, who in so many a busy kitchen has placed, not *two*, but *ten* pots, and kettles, and dishes, and pans, where but one might have been attainable, were it not for this scientific and beautiful art.

'Tis true, we may take another view and wonder how much this process has also contributed to human misery by producing cheap *cartridges*, but shall we not, with optimistic mind, think of those things that make war more deadly, as warnings which will teach men to go to war no more, and thus help forward the reign of universal peace?

An Interesting Monument.—M. Clermont-Ganneau has communicated to the Academy of Inscriptions and Belles-Lettres a note relative to a discovery made by him in an old building at Jerusalem. It was a block of stone, with a Greek inscription signifying that any stranger who should have passed that limit would be condemned to death. It is evidently a fragment of one of the posts which formed, in the temple built by Herod, a dividing line between the exterior enclosure of the Gentiles and the inner precinct reserved for the Jews. It will be remembered that St. Paul barely escaped stoning when he was accused of having introduced Greeks into the inner circle with himself. The stone has been removed to Constantinople, but a cast has been taken, which will be preserved in the Museum of the Louvre. —*Cosmos, Aug. 24, 1885.*

A NEW PROCESS FOR THE PRODUCTION OF THE METALS OF THE ALKALIS.

By Hamilton Y. Castner, of New York.

[*A Paper read before the Chemical Section of the* Franklin Institute, *October 12, 1886.*]

Mr. H. W. Jayne, President, in the Chair.

Dr. Wahl, Secretary of the Institute, presented the following communication from Mr. Castner.

Mr. President and Gentlemen:—I shall first proceed to give a brief description of the process heretofore employed for manufacturing the alkali metals, together with the defects of the same, which prevent an economical production of metal, before explaining the method I have invented for their reduction, and its advantages over the older process. Although in the following paper mention is only made of sodium, the same remarks are intended to apply to potassium, the process being practically alike in the production of either metal. The method formerly used consists in igniting, at an intense heat, an intimate mixture of nine parts of sodium carbonate, four parts of charcoal, and one part of lime in wrought-iron vessels, cylindrical in form, placed horizontally in a furnace, the said cylinders being furnished with a small tube to conduct the metallic vapors and gases produced during the reduction, into the attached condenser, wherein the vapors are condensed and the sodium obtained. The cylinders must be constructed of wrought-iron, this being the only metal possible to use that will stand the heat, and the dimensions of the same not exceed a diameter of 6 inches, or a length of 5 feet. The mixture of sodium carbonate, charcoal and lime must be finely ground and calcined, to render it more compact, previous to placing it in the cylinders. Lime is added to make the mass refractory, otherwise the alkali would fuse when the charge is highly heated, and separate from the light, infusible carbon. The carbon must be in the proportion to the sodium carbonate as four is to nine, which is found needful in practice, so as to assure each particle of soda in the refractory charge having an excess of carbon directly adjacent or in actual contact. Notwithstanding the well-known fact that sodium is reduced from its oxides at a degree of heat but slightly

exceeding the reducing point of zinc-oxide, the heat necessary to accomplish reduction by this process and to obtain even one-third the metal contained in each charge, closely approaches the melting-point of wrought-iron. Any process devised for the manufacture of sodium, by which its cost could be reduced, would have to be an improvement over the older method in one or more of the following directions, namely:

(1.) The process should be more simple in its details, and not require the care and management necessary in carrying on the process or method now used.

(2.) Performing the reduction at a comparatively low temperature and so save in the fuel and prevent the excessive destruction of iron, which at present stands for one-half the cost of the sodium produced.

(3.) By increasing the yield of sodium, as in the old process, when one-third the metal contained in the charges, is obtained, the result is considered very satisfactory.

The process which I employ consists in reducing either the hydrate or carbonate of an alkali, when in a fused state, at moderate temperatures, by the use of the carbide of a metal or its equivalent, whereby an excess of carbon is avoided and the use of lime is rendered unnecessary. The reducing substance, due to its composition and gravity, remains below the surface and is therefore in direct contact with the fused alkali. By the equivalent of the carbide of a metal, I mean, a mechanical compound of carbon and metal from which the metal cannot be separated, excepting by the aid of acids or intense heat. Such a compound I produce by coking a mixture of tar and iron (previously reduced in a fine state of division, by carbonic oxide or hydrogen). From experience, such proportions of tar and iron are used, as will produce, when the mixture is coked, a heavy mass of metallic coke, having about the composition of, iron seventy per cent. and carbon thirty per cent., equivalent to the formula, $Fe\ C_2$. This mechanical compound, after being ground, is ready for use and consists of fine particles of iron, coated with carbon, fully answering the purposes of a true carbide. I prefer to use caustic soda in the preparation of sodium, on account of its fusibility, and with it mix such quantity of the so-called "carbide;" that the carbon contained in the mixture shall not be in excess of the amount, theoretically required to

reduce all the soda to sodium, according to the following reaction,

$$3\,NaHO + FeC_2 = 3\,Na + Fe + CO + CO_2 + 3\,H;$$ or:

to every 100 pounds of pure caustic soda, fifteen pounds of "carbide," containing about twenty-two pounds of carbon, is added. The treatment of this mixture is carried on in large cast-iron crucibles, in a furnace, the general arrangements of which are as follows: The heating space of the furnace is divided into separate chambers, the dimensions of the same depending upon the size of the crucibles to be heated, and the number of these compartments are in proportion to the capacity of production desired for the furnace. An aperture is provided in the bottom of each chamber, through which the crucible may be raised by mechanical means into its position in the furnace. The necessary cover for the crucible is fixed stationary in each chamber, and from this cover projects the tube to the outside of the furnace into the receptacle for the condensation of the metallic vapors. When operating, the crucibles are charged with the mixture, made as before described, placed upon the lift, which is situated directly below the aperture made in the bottom of the chamber, and raised into the furnace. The edges of the covers are made convex, while the edges of the crucibles are concave, so that when the crucibles are raised the edges come together, and, being held from below, form a tight joint, preventing the exit of gas and vapor, excepting through the tube provided from the cover. Gas, which is used as a fuel in connection with heated air, is allowed to enter the chamber, after the crucible containing the charge is in place, and the reduction and distillation commences as soon as the crucible contents have reached the temperature of 1,000° C., the sodium being reduced in the crucible and distilled therefrom into the condenser, by passing through the tube projecting from the crucible cover. As soon as the operation is finished, the crucible is lowered and a new one containing a fresh charge is raised in its place, while the crucible just removed is cooled, cleaned and recharged. The appliances, which hold the cover in place are so arranged, that the cover may be removed whenever necessary without interrupting the process, which is practically continuous. By avoiding the careful mixing and calcining of ingredients, preparatory to charging the cylinders, and in carrying out generally the mechanical

part of the old process, the details of which require the most careful management, the method just described will be seen to have many advantages. As the charge is fused, the alkali and reducing material are in direct contact, and this fact, together with the aid rendered the carbon by the fine iron, in withdrawing the oxygen from the soda, fully explains the chemical reasons why the reduction is accomplished at a moderate temperature. Furthermore by reducing the metal from a fused mass, in which the reducing agent remains in suspension, the operation can be carried on in crucibles of large diameter, the reduction taking place at the edges of the mass, where the heat is greatest and the charge flowing thereto from the centre to take the place of that reduced. By the old process, the heat required to penetrate to the centre of the refractory charge and reduce the soda there situated in addition to the heat absolutely needful to bring about reduction, necessitates the use of wrought-iron vessels, and even when these are made small in diameter, which partially removes this great disadvantage of the method, the expensive cylinders are rapidly rendered worthless from the effects of the intense heat.

In doing away with the use of lime and an excess of carbon, the main causes which have hitherto prevented a full yield of metal are removed, and thus, with the aid of other advantages described, I am enabled to obtain fully ninety per cent. of metal, instead of thirty per cent., as formerly. By the old process, lime must be added to prevent fusion, to insure any reduction, yet at the same time it forms, with a portion of the soda, the compound known as soda-lime, and from this substance carbon reduces sodium only at the most intense heat. In practice, according to the old method, four pounds of carbon are used to every nine pounds of sodium carbonate. This is twice the amount theoretically required to reduce all the sodium, even assuming the gas resulting from the reduction to be wholly carbonic-oxide. When, however, but one-third the total amount of sodium is all that is obtained from a charge, the proportion between the sodium produced and carbon used becomes as one is to six. The effect of an excess of carbon in the mixture, which, as previously explained, is really necessary, is to produce an excessive amount of carbonic-oxide, and this, together with the excess of carbon, combines with the metallic vapors of sodium, forming various compounds, from which

the metal cannot be distilled. By reducing caustic-soda with the carbide of a metal, or its equivalent, and using only sufficient carbon to carry out the reaction stated above, the gases given off consist of hydrogen, carbonic-oxide and carbonic-acid, which mixture has little or no effect upon the vapors of sodium. The crucibles, after treatment, contain a small amount of carbonate of soda and all the iron of the "carbide" still in a fine state of division, together with a very small percentage of carbon. These residues in the crucibles are treated with warm water, and the solution of soda evaporated to recover the carbonate of soda, while the fine iron is dried, mixed with tar and coked to produce more of the so-called "carbide equivalent."

TURBINES.

By J. Lester Woodbridge, M. E., Stevens Institute of Technology.
[With an Introduction by De Volson Wood, Professor of Mechanical Engineering.]

(INTRODUCTION.)

To the Committee on Publications:

I forward to you, for publication, the graduating thesis of Mr. Woodbridge, upon "Turbines." The first well-grounded theory of these wheels was by M. Poncelet, who read a paper upon this subject before l'Academie des Séances, Paris, entitled "La Théorie des Effets Mécaniques de la Turbine-Fourneyron," published in *Comptes Rendus*, Paris, 1838. This solution was so thorough and elegant that it is often referred to as "historical" and "classical." The analysis was founded on the principles of work and energy, and his methods have been followed by many writers since his day. Rankine, in his *Steam Engine and other Prime Movers*, has given a partial solution of a special case founded on the principle of the *Moment of the Momentum*, and he has been followed by Unwin, in his article on "Hydro-mechanics," in the *Encyclopædia Britannica*, IX edition. It will be seen that Mr. Woodbridge's solution is founded upon the resolution of the pressures of elementary volumes and their moments, and is more general than either of the preceding, if not the most general solution of the frictionless turbine yet made. Yours truly,

De Volson Wood, *Prof. Mech. Eng.*

Hoboken, June 25, 1886.

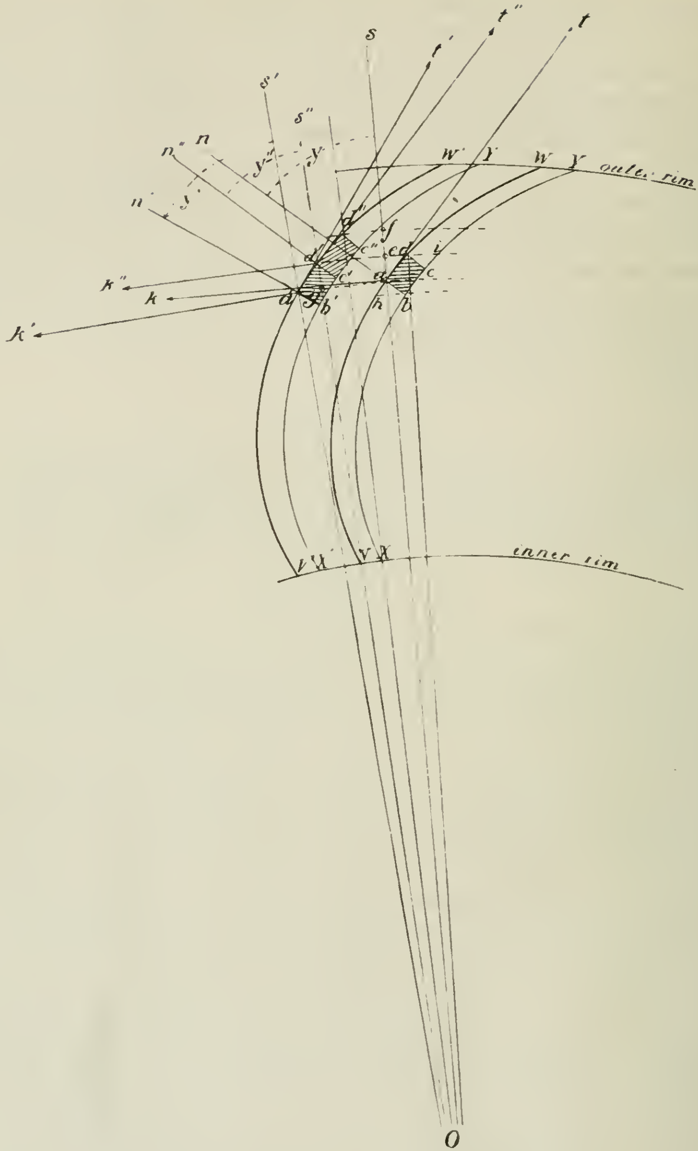


FIG. 1.

I propose to discuss the action of turbines in general. Consider first the water after it has entered the wheel and is passing

along its vanes. Conceive the water to be divided into an infinite number of filaments by vanes similar to those of the wheel, but subjected to the condition that, at each point, their width *id*, *Fig. 1*, measured on the arc, whose centre is O, shall subtend at the centre a constant angle $d\,\theta$. Conceive each filament to be divided into small prisms, whose bases are represented by the shaded areas $a'b'c'd'$, $d'c'c''d''$ and *abcd*, by vertical planes normal to the vanes making the divisions *ae*, *ef*, intercepted on the radius by circles passing through the consecutive vertices on the same vane a', d', d'', etc., equal.

Let ρ = the radius vector;
x = the height of an elementary prism;

then,

$d\rho = ae$, ef, etc.;

$\rho\, d\theta\, d\rho = abcd$, etc., = area of the base of an infinitesimal prism;

$x\,\rho\, d\,\theta\, d\,\rho$ = volume of an infinitesimal prism;

$x\,\delta\,\rho\, d\,\theta\, d\,\rho = m$ = the mass of prism, δ being its density;

$\gamma = s\,a\,n$ = angle between the normal to the vane at any point, and the radius $O\,a$ prolonged through that point;

v = velocity of a particle along the vane at ρ;

ω = the uniform angular velocity of the wheel, and

p = the pressure of the water at the point ρ.

For the element of time, $d\,t$, we will take the time occupied by one of the liquid prisms in passing along the vane through a distance equal to its own length, or, outwardly, a distance $d\,\rho$, thus making t a function of ρ, the latter being considered the independent variable. We have

$$\frac{d\,t}{d\,\rho}\, d\rho = \frac{d\,\rho}{\frac{d\,\rho}{d\,t}} = \frac{d\rho}{v \sin\gamma}.$$

Let $a\,a'$ be the distance passed through by this element circumferentially in the time $d\,t$, then

$$a\,a' = \omega\,\rho\, dt = \omega\,\rho\,\frac{dt}{d\,\rho}\, d\rho$$

and the particle $a\,c$ will, at the end of time $d\,t$, be at $a'\,c'$.

To find the reaction of a particle moving on a curved path, let the particle move from P, *Fig. 2*, along a curve to the consecutive

point, P', changing its direction by an angle, $d\gamma$, from PA to $P'B$. The velocity along PA being v, it will have acquired the

Fig 2.

velocity, $v\,d\gamma$, perpendicular to PA, in time dt, and its acceleration in the same direction will be $\frac{v\,d\gamma}{dt}$, and the force $= m\,v\,\frac{d\gamma}{dt}$ where m is the mass of the particle. That is, *the reaction of a particle, the direction of whose motion is being changed, is equal to its momentum multiplied by the rate of the angular change of its motion, and is in a direction opposite to that in which the change takes place.*

The mass m will have two motions: one along the vane, the other with the wheel perpendicular to the radius. By changing its position successively in each of these directions, both its velocity with the wheel and its velocity along the vane may suffer changes both in *amount* and *direction*, as follows:

(I.) By moving from a to a', *Fig. 1*, in the arc of a circle—

(1.) $\omega\rho$ may be increased or diminished;

(2.) $\omega\rho$ may be changed in direction;

(3.) v may be increased or diminished;

(4.) v may be changed in direction.

(II.) By moving from a' to d' along the vane—

(5.) $\omega\rho$ may be increased or diminished;

(6.) $\omega\rho$ may be changed in direction;

(7.) v may be increased or diminished;

(8.) v may be changed in direction.

These changes give rise to corresponding reactions, as follows:

(No. 1.) By the conditions imposed, $\omega\rho$ will be constant, and hence the *reaction* $= 0$.

(No. 2.) By moving from a to a', the velocity $\omega\rho$ is changed in direction from $a\,k$ to $a'\,k'$ in the time dt. The momentum is $m\,\omega\rho$, and the rate of angular change is

$$\frac{kak'}{dt} = \frac{\omega\,dt}{dt} = \omega,$$

and hence the reaction will be $m\omega^2 \rho$ in a direction radially outward. This is the *centrifugal force*, as designated by most writers. Resolving into two components, we have

$$m\,\omega^2 \rho \sin\gamma \text{ along the vane,}$$

$$m\,\omega^2 \rho \cos\gamma \text{ normal to the vane.}$$

(No. 3.) According to the conditions imposed, this value of v remains constant, hence, for this case, the reaction will be zero.

(No. 4.) In moving from a to a' the velocity along the vane, v, is changed in direction from ak to $a'k'$ at the rate ω as in No. 2.

The momentum is $m\,v$, and the force will be $m\,v\,\omega$, which acts in the direction $n\,a$, and being resolved, gives

$$0 \text{ along the vane,}$$

$$-m\,v\,\omega \text{ normal to the vane.}$$

(No. 5.) In passing from a' to d', the *increase* of $\omega\,\rho$ will be $\omega\,d\rho$, in a time dt, and the reaction will be

$$m\,\omega\frac{d\,\rho}{d\,t},$$

in a direction tangential to the motion of the wheel but backwards, and its components will be

$$m\,\omega\frac{d\,\rho}{d\,t}\cos\gamma \quad \text{along the vane,}$$

$$-m\,\omega\frac{d\,\rho}{d\,t}\sin\gamma \quad \text{normal to the vane.}$$

(No. 6.) In passing from a' to d', $\omega\,\rho$ will be changed in direction by the angle

$$a'\,O\,d' = \frac{a'\,g}{\rho} = \frac{d\,\rho\cot\gamma}{\rho},$$

and the rate of angular change will be

$$\frac{\cot\gamma}{\rho}\cdot\frac{d\,\rho}{d\,t},$$

and the momentum will be

$$m\omega\rho\,;$$

hence the reaction will be

$$m\,\omega\cot\gamma\frac{d\,\rho}{d\,t},$$

which acts radially inward, and its components are

$$- m\,\omega \cos\gamma \frac{d\rho}{dt} \qquad \text{along the vane,}$$

$$- m\,\omega \cot\gamma \cos\gamma \frac{d\rho}{dt} \qquad \text{normal to the vane.}$$

(No. 7.) By moving from a' to d', v will be increased by an amount

$$\frac{d\,v}{d\rho}\,d\rho,$$

in the time dt, and the reaction will be

$$m\,\frac{d\,v}{d\rho}\cdot\frac{d\rho}{dt};$$

which acts backward along the vane, and its components are

$$-m\frac{d\,v}{d\rho}\cdot\frac{d\rho}{dt} \qquad \text{along the vane,}$$

$$0 \qquad \text{normal to the vane.}$$

(No. 8.) In passing from a' to d', v is changed in direction by two amounts: (1.) The angle γ changes an amount

$$-\frac{d\gamma}{d\rho}\,d\rho,$$

and (2.) the radius changes in direction an amount

$$\frac{d\rho\cot\gamma}{\rho},$$

as in No. 6; hence the total change will be the sum of these, and the *rate* of change will be the sum divided by dt, which result, multiplied by the momentum $m\,v$, will give the reaction, the components of which will be

$$0 \qquad \text{along the vane,}$$

$$m\,v\left(\frac{\cot\gamma}{\rho}\cdot\frac{d\rho}{dt} - \frac{d\gamma}{d\rho}\cdot\frac{d\rho}{dt}\right) \qquad \text{normal to the vane.}$$

This completes the reactions. Next consider the *pressure in the wheel.* The *intensity* of the pressure on the two sides $a\,b$ and $c\,d$ differs by an amount

$$d\,p = \frac{d\,p}{d\rho}\,d\rho.$$

The area of the face is $d\,c \times x = x\,\rho\,d\,\theta\,\sin\gamma$, and the force due to the difference of pressures will be

$$x\,\rho\,d\,\theta\sin\gamma\frac{d\,p}{d\rho}\,d\rho.$$

If $d\,p$ is positive, which will be the case when the pressure on $d\,c$ exceeds that on $a\,b$, the force acts backwards, and the preceding expression will be *minus* along the vane. In regard to the pressure normal to the vane, if a uniform pressure p existed from one end of the vane $V\,W$ to the other, the resultant effect would be zero, since the pressure in one direction on $V\,W$ would equal the opposite pressure on $X\,Y$, *Fig.* 1. If, however, in passing from d to a, the pressure increases by an amount $-\,d\,p$, since $V\,a$ is longer than $X\,b$, the pressure on $V\,a$ will exceed that on $X\,b$ by an amount

$$-\,d\,p\,x \times a\,h = -\,d\,p\,.\,x\,.\,\rho\,d\,\theta\cos\gamma = -\,x\,\rho\cos\gamma\,d\,\theta\,\frac{d\,p}{d\,\rho}\,d\,\rho.$$

Collecting these several reactions, we have

	NORMAL TO THE VANE.	ALONG THE VANE.
(2.)	$+\,m\,\omega^2\,\rho\cos\gamma.$	$+\,m\,\omega^2\,\rho\sin\gamma.$
(4.)	$-\,m\,\omega\,v.$	$0.$
(5.)	$-\,m\,\omega\sin\gamma\,\dfrac{d\,\rho}{d\,t}.$	$+\,m\,\omega\cos\gamma\,\dfrac{d\,\rho}{d\,t}.$
(6.)	$-\,m\,\omega\cot\gamma\cos\gamma\,\dfrac{d\,\rho}{d\,t}.$	$-\,m\,\omega\cos\gamma\,\dfrac{d\,\rho}{d\,t}.$
(7.)	0	$-\,m\,\dfrac{d\,\rho}{d\,t}\,.\,\dfrac{d\,v}{d\,\rho}.$
(8.)	$+\,m\,v\left[\dfrac{\cot\gamma}{\rho}\,.\,\dfrac{d\,\rho}{d\,t} - \dfrac{d\,\gamma}{d\,\rho}\,.\,\dfrac{d\,\rho}{d\,t}\right].$	0
(9.)	$-\,x\,\rho\cos\gamma\,\dfrac{d\,p}{d\,\rho}\,d\,\rho\,d\,\theta.$	$-\,x\,\rho\sin\gamma\,\dfrac{d\,p}{d\,\rho}\,d\,\rho\,d\,\theta.$

The sum of the quantities in the second column, neglecting friction, will be zero; hence

$$m\,\omega^2\,\rho\sin\gamma - m\,\frac{d\,\rho}{d\,t}\,.\,\frac{d\,v}{d\,\rho} - x\,\rho\sin\gamma\,\frac{d\,p}{d\,\rho}\,d\,\rho\,d\,\theta = 0 \qquad (1)$$

Substituting

$$\frac{d\,\rho}{d\,t} = v\sin\gamma, \text{ and } x\,\rho\,d\,\theta\,d\,\rho = \frac{m}{\delta}$$

and dividing by $m\sin\gamma$, we have

$$\omega^2\,\rho\,d\,\rho - \frac{1}{\delta}\,d\,p = v\,d\,v. \qquad (2)$$

Integrating,

$$\left[\frac{1}{2}\,\omega^2\rho-\frac{p}{\delta}\right]^{\text{limit}}_{\text{limit}}=\left[\frac{1}{2}\,v^2\right]^{\text{limit}}_{\text{limit.}} \tag{3}$$

The sum of the quantities in the first column gives the pressure normal to the vane, which, multiplied by $\rho\ sin\ \gamma$, gives the moment. This done, we have, after substituting as above,

$$d^2 M = mv\,sin\,\gamma\left[\begin{array}{l}\omega\rho\left(\frac{\rho}{v}\ \omega\ cos\ \gamma-2\right)-\rho\ v\ sin\ \gamma\ \frac{d\,\gamma}{d\,\rho}\\ +\ v\ cos\ \gamma-\rho\,\frac{cos\,\gamma}{v\,\delta}\,\frac{d\,p}{d\,\rho}\end{array}\right].$$

Putting $mv\,sin\,\gamma=\frac{\delta\ Q}{2\ \pi}\,d\,\rho\,d\,\theta$, where Q is the quantity of water flowing through the wheel per second, and integrating in reference to θ between 0 and $2\,\pi$, we have

$$d\,M=\delta\ Q\left[\omega\,\rho\left(\frac{\rho}{v}\,\omega\,cos\,\gamma-2\right)-\rho\,v\,sin\,\gamma\,\frac{d\,\gamma}{d\,\rho}+v\,cos\,\gamma-\rho\,\frac{cos\,\gamma}{v\,\delta}\,\frac{d\,p}{d\,\rho}\right]d\,\rho$$

Multiplying (2) by

$$\frac{\rho}{v}\ cos\ \gamma,$$

we have

$$\frac{\omega^2\,\rho^2}{v}\,cos\,\gamma\,d\,\rho-\frac{\rho\ cos\ \gamma}{v\ \delta}\ \frac{d\,p}{d\,\rho}\,d\,\rho=\rho\ cos\ \gamma\ \frac{d\,v}{d\,\rho}\,d\,\rho$$

which substituted above gives

$$d\,M=\delta\,Q\left[-2\,\omega\,\rho\,d\,\rho+\rho\,cos\,\gamma\,\frac{d\,v}{d\,\rho}\,d\,\rho+v\,cos\,\gamma\,d\,\rho-\rho\,v\,sin\,\gamma\,\frac{d\,\gamma}{d\,\rho}\,d\,\rho\right] \tag{4}$$

and integrating,

$$\begin{aligned} M &= \delta\ Q\,[-\ \omega\ \rho^2+\rho\ v\ cos\ \gamma] \\ &= -\ \delta\ Q\ \rho\,[\omega\ \rho-v\ cos\ \gamma]^{\text{limit.}}_{\text{limit.}} \end{aligned} \tag{5}$$

But $\omega\ \rho - v\ cos\ \gamma$ is the circumferential velocity in space of the water at any point, and $\delta\ Q\ \rho\ [\omega\ \rho - v\ cos\ \gamma]$ is the moment of the momentum, hence, integrating between limits for inner and outer rims, *the moment exerted by the water on the wheel equals the difference in its moment of momentum on entering and leaving the wheel.* Thus we have deduced an expression which some writers have made the basis of their investigations.

Let the values of the variables at the entrance of the wheel be $\rho_1, \gamma_1, v_1, p_1$, and at exit $\rho_2, \gamma_2, v_2, p_2$.

Equations (3) and (5) become

$$\frac{1}{2}\,\omega^2\,(\rho_1^{\,2}-\rho_2^{\,2})-\frac{p_1-p_2}{\delta}=\frac{1}{2}(v_1^{\,2}-v_2^{\,2}) \tag{6}$$

$$M=\delta\ Q\,[\omega\,(\rho_1^{\,2}-\rho_2^{\,2})-\rho_1\,v_1\cos\gamma_1+\rho_2\,v_2\cos\gamma_2] \tag{7}$$

$$\therefore\ U=M\,\omega=\delta\,Q\,\omega\,[\omega\,(\rho_1^{\,2}-\rho_2^{\,2})-\rho_1\,v_1\cos\gamma_1+\rho_2\,v_2\cos\gamma_2] \tag{8}$$

Equation (8) gives the work per second in terms of the known quantities δ, ω, ρ_1, γ_1, ρ_2, γ_2, and three quantities Q, v_1, v_2 as yet unknown. These three quantities are, however, connected by the condition that the quantity of water flowing through all the sections radially is constant. Calling a_1 the entire area of all the orifices at the entrance of the wheel ($=2\,\pi\,\rho_1\,x_1$), and a_2 those at exit ($=2\,\pi\,\rho_2\,x_2$), we have

$$Q=a_1\,v_1\sin\gamma_1=a_2\,v_2\sin\gamma_2 \tag{9}$$

which reduces the number of unknown quantities to one.

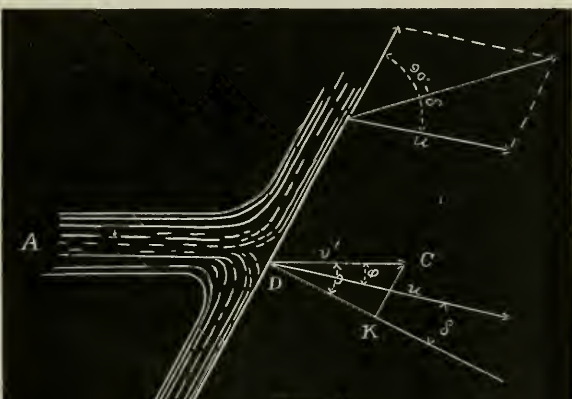


Fig 3.
(Fig 57.)

Equation (6) is the equation of the motion of the water in the wheel. Besides the velocities v_1 and v_2, it contains p_1 and p_2.

Let p_a = the atmospheric pressure,

h = the mean depth of the wheel below the surface of tail-race,

$p_t=\delta\,gh$ = the pressure due to the flooding of the tail-race;

then $p_2=p_a+p_t$.

The pressure p_1, where the water passes from the guide blades into the wheel, is unknown. Another condition is necessary, which may be found by considering the passage of the water from the guide plates into the wheel. Here it must be observed that the path of a liquid stream, either in space or relative to some moving object, is always a *continuous curve*, and never contains a sharp angle, the motion being continuous—a principle confirmed both by theory and experience. This granted, we can show the fallacy of some statements of Professor Rankine, in regard to the impulse of a stream of water on a vane. Take the case given on page 163 of Rankine's *Steam Engine, Fig. 57*, and discussed on page 169, Case V. I copy his diagram and lettering, adding a few lines that he omitted.

On page 169, he says, "In this case the easiest method of solution is the following:

"Let $v' = D\ C$, *Fig. 3*, be the velocity of the jet relatively to the vane. Let the angle $C\ D\ K$, which it makes with the normal to the vane, be denoted by θ. Resolve v' into two components, viz.:

$$D\ K \text{ normal to the vane} = v' \cos \theta,$$
$$K\ C \text{ along the vane} = v' \sin \theta.$$

"Then, according to the supposition that friction is insensible, $K\ C$ is not affected in magnitude by the vane, but $D\ K$ is entirely taken away."

Now, as shown, the stream will move in a curve on account of the self-cushion of water, and it is a well-established principle that in a frictionless fluid, *the relative velocity of a particle suffers no loss in passing around a curve*, if subjected to no other forces than the reaction of the guiding surfaces; or, in other words, if the deviation be free. Therefore, if the relative velocity of the jet was v' before impinging, the velocity along the vane after impinging will also be v', and not $v' \sin \theta$, as Rankine states it. That his solution is erroneous, may also be shown by the fact that his expression for the energy imparted to the wheel added to that lost, does not equal the original energy. Thus, according to his equation (47), the energy exerted on the wheel is

$$P\,u = D\,Q\,\frac{u\,v' \cos \theta \cos \delta}{g}.$$

To find the energy lost: if $v' \sin \theta$ be the velocity along the vane, and u the velocity with the vane, then will the velocity on leaving the vane be the resultant of these velocities, or

$$\sqrt{v'^2 \sin^2 \theta + u^2 + 2\, u\, v' \sin \theta \sin \delta},$$

and the energy will be

$$\frac{D\, Q}{2\, g} \left[v'^2 \sin^2 \theta + u^2 + 2\, u\, v' \sin \theta \sin \delta \right],$$

which, added to the energy exerted, gives

$$\frac{D\, Q}{2\, g} \left[v'^2 \sin^2 \theta + u^2 + 2\, u\, v' \cos \varphi \right], \qquad (a)$$

where $\varphi = \theta - \delta =$ the angle between the velocities u and v'. Now, the actual velocity before striking the vane was the resultant of u and v', or

$$\sqrt{u^2 + v'^2 + 2\, u\, v' \cos \varphi},$$

and the total energy was

$$\frac{D\, Q}{2\, g} \left[u^2 + v'^2 + 2\, u\, v' \cos \varphi \right] \qquad (b)$$

which exceeds equation (a); hence, according to Rankine's solution, there would be a disappearance of energy, which is contrary to the law of the conservation of energy. His error will at once be apparent by making the vane normal to the stream, in which case θ will be zero, and $D\,K = v'$, and $K\,C$ would become zero, whereas it should be v' to agree with the statement above.

Rankine makes no mention of the fact he has plainly shown in the figure—that of a division of the stream into two streams upon striking the vane, but treats it as if it were guided as in a bent tube.

On page 173, Art. 147, he again refers to the subject, and divides the pressure exerted on the vane into two parts:

"(1.) The pressure arising from the changing of the direct component $v \cos a$ of the velocity of the water into the velocity of the vane.

"(2.) The term reaction is applied to the additional action depending on the direction and velocity with which the water glances off from the vane."

This latter is the reaction due to the change in direction of the relative velocity of the jet. It is the sole cause of the pressure

exerted in all cases of free deviation, and I fail to see any meaning in his so-called "direct action" as here used. This conclusion agrees with the principles in Wood's *Mechanics of Fluids*.

Rankine remarks further, in the same article, that for a flat vane moving normally, as in his *Fig. 55* (which I copy), this

Fig 4.

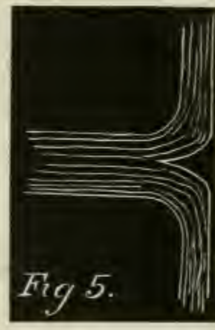


Fig 5.

direct action is the only action which occurs, but *Fig. 4* (his *Fig. 55*) shows plainly that the direct component of the velocity, $v \cos a$, is *not* changed into the "velocity u of the vane," but the stream is simply deviated, and I fail to see any distinction between the above case, which Rankine calls "direct action," in which the stream is deviated by a cusp of cushion water, and the case shown in *Fig. 5*, in which that cusp is formed of the same material as the rest of the vane.

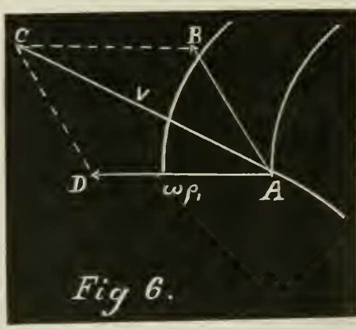


Fig 6.

In *Fig. 6*, let $A\ C$ be the tangent to the guide-plate at its extremity, V the actual velocity of the water on leaving the guide-plate, $\omega\ \rho_1 = A\ D$, the velocity of the initial rim of the wheel, then will $A\ B$ be the velocity of the stream relative to the wheel. Now, if $A\ B$ does not coincide with the tangent to the vane at A, the

stream cannot be suddenly made to coincide with the direction of the vane, or float; neither can we follow Rankine, and assume that the component of *A B* which is normal to the vane is lost. The water, by cushioning, will make its own angles, as roughly shown

Fig 7.

in *Fig.* 7. It is impossible, either practically or theoretically, to determine the new angles, and probably they are not constant; neither is it possible to determine the loss of energy due to eddying; we therefore make the hypothesis that the final direction of the guide-plates, the initial direction of the vanes, the angular velocity of the wheel and the velocity of the flow, are so related

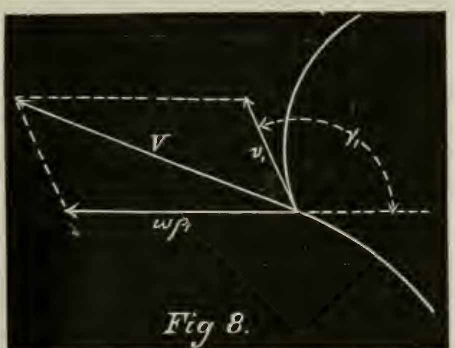


Fig 8.

that the water on leaving the guide-plates shall coincide in direction with the initial elements of the vanes. Any three of the four quantities above mentioned being fixed, the fourth becomes known by this relation. We will leave the angle of the guide-plates to be determined later.

Let V = the actual velocity of the water on leaving the guide-plates;

v_1 = the velocity relative to the vane, as before.

Then V must be the resultant of $\omega \rho_1$ and v_1, and we have *Fig. 8*,

$$V^2 = v_1^2 + \omega^2 \rho_1^2 - 2 v_1 \omega \rho_1 \cos \gamma_1 \tag{10}$$

From Bournilli's *Theorem*, we have for the flow of water in the supply chamber, the equation,

$$\frac{p_a}{\delta g} + \mathfrak{h} = \frac{p_1}{\delta g} + \frac{V^2}{2 g} \tag{11}$$

$\mathfrak{h}$ being the mean height of the surface of the water in the reservoir above the wheel. We thus have two equations (10) and (11), introducing one new unknown quantity. Eliminating V in (10) and (11), we have

$$v_1^2 + \omega^2 \rho_1^2 - 2 v_1 \omega \rho_1 \cos \gamma_1 = 2 g \mathfrak{h} - \frac{2 p_1}{\delta} + \frac{2 p_a}{\delta} \tag{12}$$

Substituting in equation (6) $p_2 = p_a + g \delta h$, we have

$$\omega^2 \rho_1^2 - \omega^2 \rho_2^2 - \frac{2 p_1}{\delta} + \frac{2 p_a}{\delta} + 2 g h = v_1^2 - v_2^2 \tag{13}$$

Adding (12) and (13), we have

$$2 \omega^2 \rho_1^2 - \omega^2 \rho_2^2 = 2 g (\mathfrak{h} - h) + 2 v_1 \omega \rho_1 \cos \gamma_1 - v_2^2 \tag{14}$$

From (9) and (14), H being substituted for $\mathfrak{h} - h$, we find

$$v_1 = \frac{a_2 \sin \gamma_2}{a_1 \sin \gamma_1} \left[\omega \rho_1 \cos \gamma_1 \frac{a_2 \sin \gamma_2}{a_1 \sin \gamma_1} + \sqrt{\omega^2 \rho_1^2 \cos^2 \gamma_1 \frac{a_2^2 \sin^2 \gamma_2}{a_1^2 \sin^2 \gamma_1} + \omega^2 (\rho_2^2 - 2 \rho_1^2) + 2 g H} \right] \tag{15}$$

$$v_2 = \frac{a_1 \sin \gamma_2}{a_2 \sin \gamma_2} v_1 = \left[\omega \rho_1 \cos \gamma_1 \cdot \frac{a_2 \sin \gamma_2}{a_1 \sin \gamma_1} + \sqrt{\omega^2 \rho_1^2 \cos^2 \gamma_1 \frac{a_2^2 \sin^2 \gamma_2}{a_1^2 \sin^2 \gamma_1} + \omega^2 (\rho_2^2 - 2 \rho_1^2) + 2 g H} \right] \tag{15a}$$

$$Q = a_2 \sin \gamma_2 v_2 = a_2 \sin \gamma_2 \left[\omega \rho_1 \cos \gamma_1 \frac{a_2 \sin \gamma_2}{a_1 \sin \gamma_1} + \sqrt{\omega^2 \rho_1^2 \cos^2 \gamma_1 \frac{a_2^2 \sin^2 \gamma_2}{a_1^2 \sin^2 \gamma_1} + \omega^2 (\rho_2^2 - 2 \rho_1^2) + 2 g H} \right] \tag{16}$$

The efficiency will be, from equation (8),

$$E = \frac{1}{g\,H}\left\{\omega^2\rho_1^2 - \omega^2\rho_2^2 + \omega\left[\rho_2 \cos\gamma_2 - \frac{a_2 \sin\gamma_2}{a_1 \sin\gamma_1}\rho_1 \cos\gamma_1\right] \times \right.$$

$$\frac{a_2 \sin\gamma_2}{a_1 \sin\gamma_1}\,\omega\,\rho_1 \cos\gamma_1 +$$

$$\left.\sqrt{\omega^2\left(\rho_2^2 - 2\,\rho_1^2\right) + 2\,g\,H + \frac{a_2^2 \sin^2\gamma_2}{a_1^2 \sin^2\gamma_1}\,\omega^2\,\rho_1^2 \cos^2\gamma_1}\;\right\} \qquad (18)$$

To find the angular velocity that will give a maximum efficiency, make $\frac{d\,E}{d\,\omega} = 0$ in (18). For brevity, make

$$m = -\rho_1 \cos\gamma_1 \frac{a_2 \sin\gamma_2}{a_1 \sin\gamma_1} + \rho_2 \cos\gamma_2 \qquad (19)$$

$$b = \rho_1 \cos\gamma_1 \frac{a_2 \sin\gamma_2}{a_1 \sin\gamma_1} \qquad (20)$$

$$l^2 = \rho_1^2 \cos^2\gamma_1 \frac{a_2^2 \sin^2\gamma_2}{a_1^2 \sin^2\gamma_1} + \rho_2^2 - 2\,\rho_1^2 \qquad (21)$$

$$s^2 = \rho_2^2 - \rho_1^2 - m\frac{a_2 \sin\gamma_2}{a_1 \sin\gamma_1}\rho_1 \cos\gamma_1. \qquad (22)$$

Then will $\frac{d\,E}{d\,\omega} = 0$, give

$$\omega\,s^2\sqrt{\omega^2\,l^2 + 2\,g\,H} = m\,\omega^2\,l^2 + m\,g\,H; \qquad (23)$$

$$\therefore\ \omega^2 = \frac{g\,H}{l^2}\left[\frac{s^2 - \sqrt{s^4 - m^2\,l^2}}{\sqrt{s^4 - m^2\,l^2}}\right] \qquad (24)$$

and this substituted in (18) will give the maximum efficiency for any turbine, and in (16) will give the quantity of water discharged.

(*To be Continued.*)

Errors in Delicate Weighing.—M. Hennig de Wurtzbourg having noticed some incomprehensible differences in the weights of equivalent quantities, undertook some minute investigations, which showed that balances of precision are often influenced by the electric state of the glass cage which surrounds them. This electricity influences the small auxiliary slides which are placed upon the beam of the balance in order to make it more sensitive. The error resulting from this influence may amount to 600 milligrammes when the cage is strongly charged, and two hours afterwards there may still be an error of ten milligrammes.—*Cosmos, Oct. 5, 1885.*

The SCHLESINGER SYSTEM of ELECTRIC TRANSMISSION.

By W. M. Schlesinger, of Bradford, England.

[*A Paper read at the Stated Meeting of the* Franklin Institute, *held Wednesday, October 20, 1886.*]

Although but a short time has elapsed since the first successful practical application of electricity as motive-power for railroads, nevertheless the number of electric roads now in operation is a comparatively large one. Not counting the roads built in mines, or small ones running on piers, there are at the present time about ten operated in Europe, and the same number in America. Of these, about half the number run only one car, while the others run from two to ten.

The gain of much practical experience is the natural outcome of the operation of these roads, and it is not to be wondered at, therefore, that a great many improvements have been made since Siemens ran his first train in Berlin, in 1879.

Electric railroads may be divided into two large classes. To the first belong all those that derive their current direct from the generators by means of conductors, with which they stand in constant communication, and to the second belong all those operated by means of batteries, primary or secondary. As the road to which I wish to call your attention belongs to the first class, I will only mention of the second class that primary batteries are no longer used for the propulsion of cars, whereas secondary batteries have been employed with success.

The requirements of a road of the first class are generators, motors, stationary conductors along the route, and movable conductors connecting these with the motors.

According to the position of the stationary conductors, the systems of the first class are subdivided into three classes. To the first belong all those that have the conductors on the surface. An insulated central rail generally forms the lead. The uninsulated rails on which the car runs are the return conductors. In some cases, as in Ireland, on the Portrush road, the central rail is dispensed with, the current being transmitted to the motor by

the rails on which the car runs. In this case, the wheels of the car have, of course, to be insulated from each other.

The advantages of these roads are their great simplicity and strong mechanical construction; their defects are that, owing to their unprotected conductors, they are dangerous to persons or animals crossing the track, and therefore better adapted to suburban roads. For the same reason the E. M. F. used with these roads ought not to be larger than 150 volts.

Part of these defects are remedied in the systems of the second class, which comprises all roads carrying the conductors overhead on poles. As it is impossible with these for persons to come in contact with both conductors at the same time, higher E. M. F. can be used, and everyone acquainted with the theory of electric-power transmission knows of what importance it is for the efficiency as well as economy of the plant to use the highest possible E. M. F. The defects of these systems are that they are mechanically not as strong as those of the first class, and that the poles required for them form an obstruction in the streets. Roads of this kind, although they may be suffered in smaller towns having broad streets, would be too great an obstruction to be introduced in the crowded thoroughfares of larger cities.

To the third class belong those roads having the conductors underground in a conduit, access to them being had by means of a slot in the latter. Roads belonging to this class have only recently been built, and but two are in operation at the present moment. These systems combine the advantage of those of the first class, in having ample mechanical strength, with that of the second in being able to use high E. M. F., and in addition to these, they do not form an obstruction to traffic in any way.

Of the two roads belonging to this class, one is located in England and the other here in Philadelphia. This latter road was not built for the purpose of making it permanent or profitable, but simply to demonstrate to the public the practicability of the system. By kind permission of President E. B. Edwards, of the Ridge Avenue Passenger Railway Company, we were allowed to use the track of that company, between their depot and South Laurel Hill, a distance of 2,600 feet, and having a three and one-half per cent. grade near the end at Laurel Hill.

Before giving a description of this road, I will try to show what

is necessary to make a road of this kind successful. The great secret of success in electrical plants of all kinds is, as you all know, good insulation and simplicity of construction. With surface and overhead conductors, good insulation is comparatively easily gained; not so with underground conductors. The slot leading to the conduit gives access not only to the collectors, but also to water, dirt and snow. The first requirement of the conduit, therefore, is to prevent these from coming into contact with the insulation, the second is to allow an easy and quick removal of these foreign substances.

In our present conduit we have tried to attain above requirements by building it in the following manner:

The conduit is 9 inches deep by 3½ inches wide, its bottom is formed of a wooden plate 1 x 3½ inches, and against this the sides of the conduit are pressed and at the same time secured to the cross-ties by spikes. The main sides are wooden beams 4 x 7 inches and 15 feet long, and to this an iron rail forming the top of

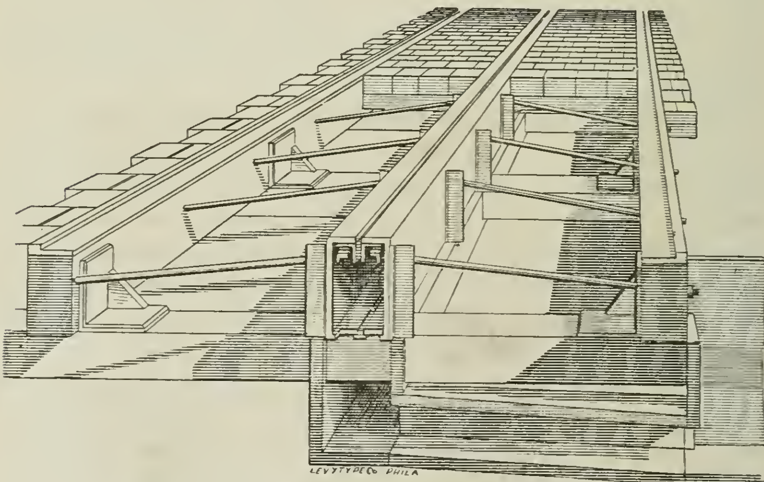


FIG. 1.—Section showing Roadbed and Conduit.

the conduit is secured by a number of bolts. This construction is, of course, not practical for permanent roads. These we have decided to build of strong channel iron 9 inches high and from 15 to 20 feet long. Angle-iron is riveted to the top flange in the manner shown in the accompanying *Fig. 1*. In this it will be seen that one

of its flanges pointing downward parallel to the main side of the channel-iron, forms one side of the slot. In the inverted troughs, formed in this manner, the conductors are fastened so that the contact-sides (*i. e.*, on which the contact-pieces rub), is the lower side. The conductors are much narrower than the troughs, so that contact with the sides is impossible. Any dirt or water entering through the slot will therefore fall to the bottom of the conduit without interfering with the insulation. The conductors are made of copper bars, to the lower side of which channel-iron is fastened. The object of the latter is to protect the copper from being worn away by the rubbing contact-pieces of the collectors and at the same time to keep these latter in their places. The conductors are at each end of the section shorter than the latter and are there replaced by wooden mouldings, the object of which is to protect the insulation from water or dirt getting in between two following sections. These wooden mouldings fill up the whole space, between channel-iron and angle-iron and come within one-half inch of the conductors. The copper of one section is connected to that of the following on our road on Ridge Avenue, by means of well insulated cable soldered to the copper, and passing through holes to the

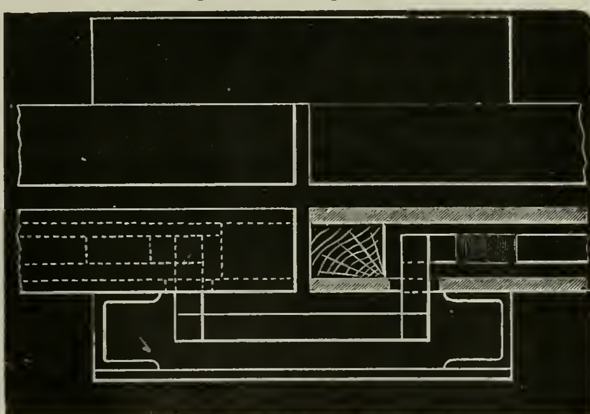


FIG. 2.—Plan showing the Connection between two following Sections.

outside of the conduit where the connection between the cable ends is made. After being well insulated this connection is placed in a recess cut in the wooden beam. This recess is then covered with a plank and filled up with pitch. For the sake of convenience when testing, these connections are at certain intervals

surrounded by large, wooden boxes, with removable lids instead of being placed in the recesses. *Fig. 2*, shows the connection between two following sections of our new conduit. Instead of insulated cables, the connection is made with pieces of copper, protected by an iron box the lid of which is removable. The object of making the connections in such a manner is to allow any section to be tested or cut out of the circuit, by taking the current around it through an insulated cable, without interfering with the conduit or the working of the road. Then again, as all sections are to be made of exactly the same size, it is possible to replace a faulty one in a short time by a new one.

To allow the removal or exchange of the collectors, or the inserting of brushes for cleaning purposes, openings are provided for at proper distances. These are covered by strong cast-iron plates, carrying in place of conductors wooden moulding. The current is taken around these traps, on the outside of the conduit, by means of insulated cable. This is done for the purpose of avoiding an interruption of traffic by the opening of these traps, and to prevent the conductors from being damaged through careless handling.

As above description shows, all appliances are secured to the top of the conduit, leaving a perfectly free space below, nearly seven inches deep. A device for cleaning the conduit can therefore be passed along the bottom, without interfering with the conductors, and the dirt that has fallen through the slot can be swept into pits, from where it is removed by hand. These pits are connected with the sewers to allow the rain-water to pass off. Braces at the sides of the sections keep the slot at the proper size.

The insulation used is red fibre, well soaked in paraffine. Both lead and return conductors, are perfectly insulated, as the slight advantage in cost, gained when using the rails as return conductor, is more than balanced by the greater security from stoppages, caused by faults in the insulation.

The insulation resistance of each conductor was about 12,000 ohms for 500 feet, while laying the road. This would have given 2,300 ohms for each side, the length of the road being 2,600 feet. On the 29th September, the one side showed about 800 ohms. The fall of insulation resistance is due principally to the fact, that the first 500 feet, which have been in the ground now for

three-quarters of a year, were not built with the same care as the rest; then again, the distance between the conductors and side of the conduit was made too small, being only one-eighth inch. Another reason is, that owing to the comparatively few hours we are running every day, it was impossible to keep the caterpillars out of the conduit. These crept up between the conductors and the sides of the conduit and cocooned there. Nevertheless, the resistance between conductors is so large that, with the E. M. F. we are using of about 160 volts, the ammeter does not indicate the slightest leakage. The insulation resistance between conductors is about 880 ohms, and the E. M. F. being 160 volts, the loss through leakage in the conduit is two-elevenths ampères, or twenty-nine watts, or about one–twenty-fifth horse-power. On the 4th September, the whole conduit had been submerged from end to end by means of four fire-plugs, situated along the road. On starting up, the loss was nearly eight ampères, but after the first trip, this was reduced to about three ampères, and, after two hours run, the leaking had stopped entirely. After a very heavy rain, the loss on starting up generally amounts to from one to two ampères, but stops after the first trip.

The main features of the conduit can be summed up as follows: Perfect protection of insulation against dirt or water coming in through the slot, or the spaces between the sections; facilities for cleaning it out; easy access to the connections for the purpose of testing or cutting out a faulty section; facilities for exchanging the latter for a new one, without interfering with the working of the road; easy access to the interior by means of the traps, and perfect drainage.

Perhaps the most difficult part of the whole problem was to devise a good collector, mechanically as well as electrically satisfactory. To give at all times good contact, this latter had to be made independent of the oscillations of the car, and at the same time fastened strong enough to it to enable it to overcome any obstruction in the shape of stones or wedges placed in the slot. The first collector tried rested on four wheels, and was pulled along by the car by means of strong chains. But although this fully accomplished all the electrical requirements, yet it had to be abandoned for practical mechanical reasons. Instead of this, the collector now in use was devised, and this combines good

mechanical, with excellent electrical qualities. It consists, as *Fig. 3* shows, of a cast-iron frame carrying a strong finger reaching into the slot to remove all obstructions. This frame is secured by means of a bolt to the car, in such a manner as to allow it perfectly free motion in a vertical, and sufficient in a horizontal plane. Through a fork in this frame a phosphor-bronze casting passes, fastened to it by means of a bolt, so as to swing freely in a vertical plane and to have enough side-play. This casting passes into the slot, and carries two steel springs well insulated from it and from each other. A strong spiral spring, which takes up all the irregularities in the motion of the car, presses the springs against the conductors. To furthermore insure good contact, the phosphor-

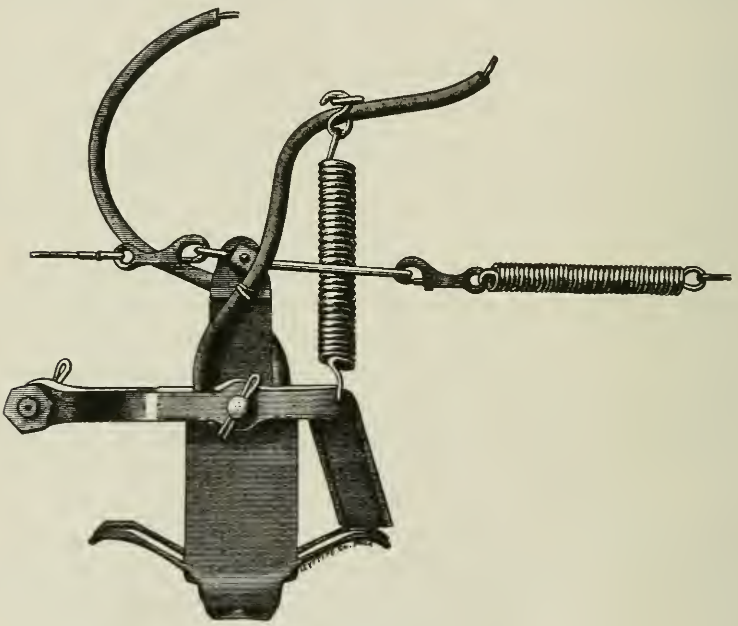


FIG. 3.—The Collector.

bronze casting is connected by springs and wire ropes to a lever on the front platform. With this lever, the casting is tilted in such a manner that in going forward the front parts of the contact-springs, and in going backward the back parts are moved away from the conductors. Two such collectors are supplied to each car, one having the cast-iron finger pointing forwards, the other backwards. The contact between springs and conductors is per-

fect, as the incandescent lamps in the car and the ammeter at the station show. The connection between the contact-springs and the motor on the car is made by means of well-insulated wires, protected where they pass through the slot by steel plates riveted to the phosphor-bronze frame.

Among the advantages that can be claimed for the electric motor over any other motor, small size and weight undoubtedly take a prominent place. Owing to these two properties, it was possible for us to place the motor on the car itself that is intended to carry the passengers, thus doing away with the cost, as well as extra power required by a separate locomotive car. The motor on our car on the Ridge Avenue is fastened to it below the body of the car, between the two axles, and, therefore, does not diminish the seating capacity in the least. The middle of the car was thought to be preferable to any other place, not only because its frame is strongest there, but also because the weight of the motor is equally distributed on both axles. The power is transmitted from the armature shaft to the wheels by chain-gearing. Unless the grades of the road are very steep, it is sufficient to connect one axle only with the motor; with steep grades and heavy loads, it is preferable to transmit the power to both axles, as then the entire weight of the car is effective for tractive power.

To allow easy access to, and good supervision of, the brushes of the electro-motor, the commutator has been placed outside the bearings, the connecting-wires passing through the hollow shaft. The motor in use on our car weighs 1,850 pounds, is built of cast-iron, and can furnish thirteen horse-power. By using the best possible material, like wrought-iron, for the magnets, both weight and size can be very much reduced. The motor designed especially for the purpose weighs about 1,350 pounds, takes up less room, and can furnish seventeen horse-power, or enough power to haul two cars on not too heavy grades. To protect the motor from dirt, dust and water, it is surrounded by a wooden box, having doors at the side, through which the commutator, on the one side, the transmission on the other, can be inspected.

The speed regulation of the car was at first effected by regulating the strength of the field. It is a well-known fact that the work done by a motor within a given time is at its maximum if the counter E. M. F. is half the E. M. F. and sinks, the nearer the

former gets to the latter. On the other hand, the torque is greater the stronger the field, and as the load with which a motor can start up is dependent on this, it is essential to start up with the strongest possible field. When in motion, the required speed is attained by weakening the field and thus the counter E. M. F. Our motor being a shunt machine, it was, of course, necessary to let the main current take several turns round the field-magnets, as, on closing the armature circuit, the low resistance of the latter before revolving would, of course, short-circuit the field-circuit. As far as the motor was concerned, this regulation was very satisfactory, but owing to the fact that one car only was being operated, it was found that the strain on starting was too great for both generator and steam-engine. The regulation was therefore changed to one by means of wire resistance placed under the seats in the car. To allow quick and easy starting up, the field-magnet circuit is always in connection with the conductors in the conduit.

On leaving the conduit through the collectors, the current is taken directly to a regulator-box on the front platform of the car, and in this the connections for the different circuits are made. To allow the cars to be run by unskilled men, like ordinary drivers, the regulation is so arranged that one lever only is required to operate the car. This lever not only allows the car to be started up either forward or backward, but also controls the speed of the same, regulates the light circuit, and controls the electric brake. A diagram, showing the connections in the box, is shown in *Fig. 4*.

The electric brake is composed simply of a large solenoid attached to the car in a horizontal position. The core is made partly of brass and partly of iron and, resting on brass rollers, has a motion of nearly eight inches. It connects by means of a chain with the brake-lever, ordinarily worked by the hand-brake. By putting in or taking out resistance in the solenoid circuit, the pressure executed by it can be regulated at will. The feature of the brake is that it can only be applied when the connections between armature and conduit are interrupted. It is thus impossible to endanger the motor by starting up with the brakes on, or by applying the latter while the motor is propelling the car.

In practice, it will invariably be found that, no matter how good the motor, or what automatic regulation is employed, the practical neutral line will shift from one side to the other of the theoretical

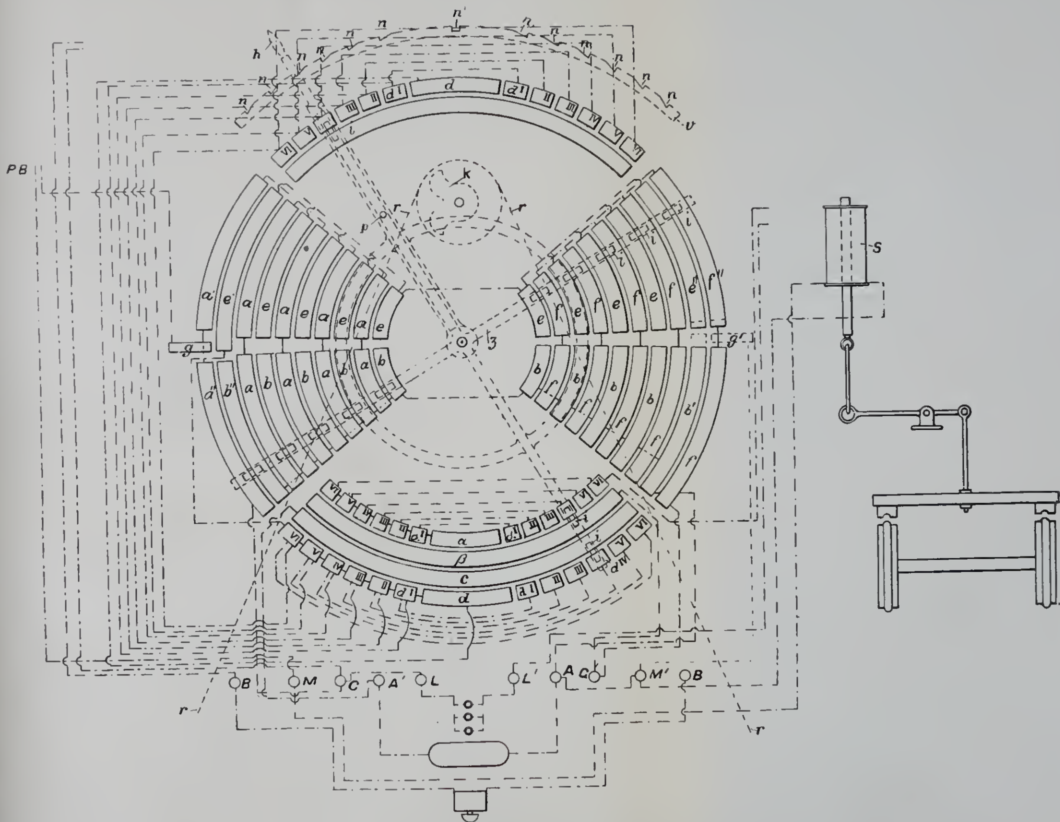


FIG. 4.—Plan showing Connections for Starting, Stopping and Speed Regulating.

neutral line on reversing the motion of the armature. To gain the best results and prevent sparking, it is therefore necessary to provide for means by which the brushes can be shifted to follow the neutral line. To effect this, we have connected the brush-holder by means of wire-ropes to a fork, operated by the lever on the front platform. On moving the lever to either side, the fork is moved a certain distance, thus setting the brushes to one or the other side of the theoretical neutral line. When properly adjusted, the motor runs without a spark at the commutator; the brushes are trimmed every three or four days, the wear they show being mostly due to friction.

To supply the required current, a dynamo is used, which is the exact counterpart of the motor. The armature is of the drum-type, and the winding a modification of the Hefner-Alteneck winding. Owing to the fact that the current taken from the generator is very variable, especially when running one car only, it is impossible to use a series dynamo. On the other hand, it is rather expensive to make a shunt dynamo, giving as high an E. M. F. as 500 or 600 volts. Owing to this and other considerations, we use separately excited field-magnets in our generators and have carried this out on Ridge Avenue, although we there only use an E. M. F. of 160 volts. The exciter used is a small Hochhausen dynamo.

As to the efficiency of the road, it is impossible to give any exact data. The average speed of the car is a little above nine miles per hour; the weight of the car alone is about 5,000 pounds, the weight of the motor and other appliances is 2,100 pounds, giving the total weight of the empty car as 7,100 pounds, or nearly three and one-quarter tons. The capacity of the car is forty-five passengers, which, at 140 pounds per passenger, give an additional weight of 6,300 pounds, a total weight of 13,400 pounds, or about six tons. The current required on the level is between fifteen and seventeen ampères, the E. M. F. being about 160 volts; on the curve on the grade about forty-five ampères are required, the E. M. F. being only 135 volts, owing to the slowing-up of the steam-engine.

Note.—Since this was written the connections of the first 500 feet of the conduit have been renewed, and when testing on the 18th of this month the insulation resistance of the one conductor was found to be between 1,500 and 2,000 ohms.

DISCUSSION.

MR. ———.—"How is it proposed to run more than one car?"

MR. SCHLESINGER.—"By using a constant E. M. F. and placing the cars in multiple arc. The resistance of the motor is due to the resistance of its wire, and to the counter E. M. F. Of these, the first is a constant, but the second varies according to the speed of the car. Supposing the motor to have no regulation, its resistance will increase when the speed increases, and decrease when the latter decreases. The result is that with a higher speed, the current passing through the motor, decreases, and, according to the laws governing electric power transmission, the work performed decreases also. Should the speed decrease, the current passing through the motor, and the work performed by the latter will increase. This means that with a given load and a given E. M. F. the motor, if no regulation is used, can only acquire a certain speed, and only a certain amount of current will therefore be able to pass through it, no matter what amount is produced by the generator. It is therefore just as easy to run more than one car, as it is to burn more than one incandescent lamp on the same circuit."

MR. WM. TILGHMAN.—"What is the cost as compared with that of horses?"

MR. SCHLESINGER.—"By taking into account the cost of coal, attendance, maintainance of plant and the interest on capital, the power required per car per day will cost from $2.50 to $3. The power when supplied by horses costs about $6."

MR. W. CURTIS TAYLOR.—"How does it compare with the cable roads?"

MR. SCHLESINGER.—"The cost of the plant required for an electric road is about one-fourth of the cost of that required for a cable road, the efficiency of the power transmission is from two to three times larger, and the wear and tear by far smaller. It will cost much less therefore to operate an electric road than it will to operate a cable road."

MR. W. CURTIS TAYLOR.—"What is the cost of construction per mile?"

MR. SCHLESINGER.—"To change a horse railroad into an electric road with underground conductors, will cost from $20,000 to $25,000 per mile. This includes all the necessary machines.

MYSTERY GOLD.

The (London) *Chemical News*, of May 1, 1885, contains an article on an alloy used in the manufacture of "bogus" gold jewelry. It is stated that the composition of the alloy is:

Silver,	2·48
Platinum,	32·02
Copper (by difference),	65·50
	100·00

The color is described as resembling nine carat gold, and the alloy is said not to be attacked by nitric acid.

A melt of the above-mentioned ingredients in the proportions stated, made for me by the late Mr. Bishop, gave results quite different.

After several meltings, to insure complete admixture, the resulting alloy has a white color resembling zinc, rolls with some difficulty and with a disposition to split or crack on the edges, and is quite readily attacked by nitric acid. C. B.

The TATHAM DYNAMOMETER.

AN ATTACHMENT DESIGNED TO ELIMINATE ALL JOURNAL FRICTION FROM THE INDICATIONS OF THE SCALE-BEAM.

In using the Tatham dynamometer, to measure the force absorbed by any machine in operation, the method adopted is, first, to couple the shaft of the dynamometer with that of the machine on trial and make the observations of force and velocity; then (without delay) to uncouple and make the same observations, running the dynamometer alone, taking care to run at the same uniform velocity as before. This difference between the two measurements is taken as the power applied to the shaft of the machine on trial.

In each measurement, the scale-beam of the dynamometer tells the difference between the forces exerted by the two parts of the motor-belt upon the pulley.

The first measurement gives the sum of the following resistances:

(1.) The force required to run the machine on trial.

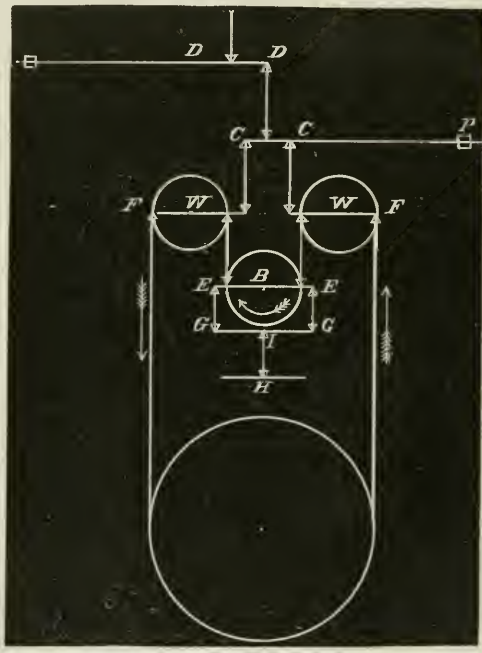
(2) The friction of the dynamometer shaft *B* in its journals.

(3.) The force required to bend and straighten the two parts of the motor-belt.

(4.) The effects of the air-currents and resistances created by high velocities.

The second measurement gives the sum of the second, third and fourth items, and the difference between the two measurements should give the first item, and this must be the case if the circumstances remain constant.

It would, of course, be better if the net power absorbed could be ascertained by one observation, but this is impossible.



As an approximation, however, to this result and for the benefit of tender consciences, I desire to present a sketch of an attachment to the dynamometer, which, I think, would completely eliminate the journal friction of the shaft *B* from the readings of the scale-beam, leaving the items (3) and (4) to be afterwards measured and subtracted as before.

The figure represents a skeleton of the dynamometer. The

journal-boxes which carry the shaft *B* are placed upon a lever-frame *E E* (or side levers), hung from the cradles which carry the pulleys *W W*, by links and knife-edges coincident with the lines of effort of the belt. The frame *E E* is linked by parallel links *E G*, to a parallel lever-frame or side levers *G G*, suspended at the centre knife-edge *I*, from the frame of the machine at *H*.

The force of the journal friction of the shaft *B*, tending to revolve the lever-frame *E E* in the direction of the arrow, will be communicated by the intermediate links and cradles to the scale-beam *C C*, and will deduct itself from the readings of the beam.

W. P. T.

On the new ARTIFICIAL RUBIES.*

By George F. Kunz.

The subject I take the liberty of presenting this evening is of considerable interest at present, both financially and as a notable example of the manner in which the microscope is constantly called into use in almost every profession. Early in the past summer, the "Syndicat des Diamants et des Pierres Précieuses," of Paris, was informed that certain stones that had been sold as rubies from a new locality, were suspected to be of artificial origin. Geneva houses, it was said, had put them upon the market, and it was surmised that they were obtained by the fusion of large numbers of small rubies worth a few dollars a carat into one fine gem worth from $1,000 to $2,500 a carat.

Samples of these artificial stones were kindly procured for me by Messrs. Tiffany & Co.; but I was not permitted to break them for the purpose of analysis, to observe the cleavage, or to have them cut so that I might observe the optical axes more correctly. I should at any time have detected these stones at the first glance with a pocket lens, the whole structure being that of a fused or artificial production. Examination elicited the following facts:

The principal distinguishing characteristic is the presence of large numbers of *spherical bubbles*, rarely pear-shaped, or having stringy portions showing how the bubbles had moved. The ends of these bubbles are always rounded like those present in glass or

* Read before the New York Academy of Sciences, October 4, 1886.

fused mixtures. Viewed *en masse*, the bubbles have a cloudy appearance or are arranged in wavy groups; individually, they seem to be filled with air or gas, and form part of a cloud, the rest having the waviness of a fused mixture. A few appeared to inclose inner bubbles.

In natural rubies, the cavities are always angular or crystalline in outline, and are usually filled with some liquid. Sometimes they are arranged with the lines of growth, forming part of a *feather*, as it is called by the jewellers. Hence the difference between these natural cavities and those caused by fusion is easily marked, even with the pocket lens. I have failed to find in any of these artificial stones even a trace of anything like a crystalline or angular cavity.

Another distinguishing characteristic is, that in many genuine rubies, we find a silky structure (called *silk* by jewellers) which, if examined under a microscope, or under a $\frac{4}{10}$ or $\frac{8}{10}$-inch objective, is found to be a series of cuneiform or acicular crystals, usually iridescent, and arranged parallel with the hexagonal layers of the crystal. When sufficiently numerous, they produce the asteria or star effect, if cut in *cabochon* form with the centre of the hexagonal prism on the top of the cabochon. I have failed to find any trace of these included *cuneiform* or *acicular* crystals in any of the artificial stones, or even any of the marking of the hexagonal crystal that can often be observed when a gem is held in favorable light so that the light strikes obliquely across the hexagonal structure.

Dr. Isaac Lea* has suggested that these acicular crystals are rutile, and my own observation lends strong confirmation to his view. (See paper on "Star Garnets," *New York Academy of Sciences*, May, 1886.) It is my conviction that they were deposited from a solution, either hot or cold, while the corundum was crystallizing, and I doubt whether they will ever be found in any substance formed from fusion. The hardness of these stones I ascertained to be about the same as that of the true ruby, 8·8, or a trifle less than 9, the only difference being that the artificial stones are slightly more brittle. The testing-point used was a Siamese-green sapphire, and the scratch made by it was a little broader but no deeper than that made on the true ruby. As is usually the case with a brittle material, after several trials I faintly

* See *Proceedings of the Philadelphia Academy of Sciences*, February 16, 1869, and May, 1876.

scratched it with chrysoberyl, which will also slightly mark the true ruby.

The specific gravity I found to be 3·93 and 3·95, that of the true ruby varying from 3·98 to 4·01. The difference between the false and true in this respect is, therefore, very small, and is doubtless due to the presence of the included bubbles. As a practical test of genuineness, this method is too delicate for jewellers' use, because, if a true ruby were not perfectly clean, or a few of the bubbles that sometimes settle on gems in taking the specific gravity were not removed, it would appear to have about the same specific gravity as these artificial stones. On examination with the dichroscope, I found that the ordinary image is cardinal-red; the extraordinary, a yellowish salmon-red, like the true ruby of the same color. Under the polariscope, I noted the appearance of what I believe to be annular rings, although I was unable positively to prove their presence, owing to the shape of the stones. Under the spectroscope, the red ruby line is visible, as in the true ruby. The color of all the stones I examined was good, but none was so brilliant as a very fine ruby. The cabochons were all duller than fine true stones, though better than poor ones, and had a remarkable uniformity of color, showing that they were made by one exact process or at one time. The cloudy appearance in all of them is doubtless due in part to the presence of bubbles. The optical properties of these stones are such as to make it evident that they are individuals or parts of individual crystals, and not agglomerations of crystals or groups fused by heating.

The matter was referred by the syndicate to M. Friedel, of the Ecole des Mines, Paris, who was furnished with samples of the stones for analysis. He reported finding the same round or pear-shaped bubbles, and determined the hardness and specific gravity to be about the same as of the true ruby. On analysis, he found them to consist of alumina, with a trace of chromium for the coloring matter. The cleavage was not in all cases distinct. The rough pieces given to him as samples of the stones in their native state had all been worked, so that nothing could be learned of their crystalline condition. When properly cut according to axes, they showed the annular rings. The extinction by parallel light was not always perfect, which he ascribed to the presence of the

bubbles. He states that he himself has formed small red globules with these inclusions by fusing alumina in the oxy-hydrogen flame; and although he has no positive evidence, he believes these stones to be artificially formed by fusion.

On the receipt of M. Friedel's report, the syndicate decided that all cabochon or cut stones of this kind shall be sold as *artificial*, and not precious gems. Unless so marked, all sales of these stones will be considered *fraudulent*, and are punishable under the penal code. It was also determined that all sales so far made, amounting to between 600,000 and 800,000 francs, should be cancelled, and the money and stones returned to their respective owners.

In my opinion, these artificial stones were produced by some process, similar to that described by MM. Fremy and Feil (*Comptes Rendus*, foot-note, 1877, t. lxxxv., p. 1029), by fusing an aluminate of lead with silica in a silicious crucible, the silica uniting with the lead to form a lead glass, and liberating the alumina, which crystallizes out in the form of corundum in hexagonal plates, with a specific gravity of 4·0 to 4·1 and the hardness of the ruby. The color of the ruby is produced by the addition of chromium salt. By this method rubies were formed that, like the true stone, were temporarily decolorized by heating. It is not likely that they were formed by Gaudin's method (*Comptes Rendus*, t. lxix., p. 1342), by exposing amorphous alumina to the flame of the oxy-hydrogen blow-pipe, thus fusing it to a limpid fluid, which, when cooled, is said to have the hardness of the true ruby, but a specific gravity of only 3·45. Nor is it more probable that they were obtained by fusing small natural rubies or pieces of corundum, because by this method the specific gravity is lowered to that of the product of Gaudin. The same holds good of quartz or beryl.

The action taken by the syndicate has fully decided the position that this production will take among gem dealers, and there is little reason to fear that the true ruby will ever lose the place it has occupied for so many centuries. This only shows, however, another of the triumphs of the modern science of chemistry. Although some may be willing to have the easily attainable, there are others who will want, what the true is almost becoming to-day, the unattainable. The one is Nature's gem, and the other that made by man.

ABSTRACTS FROM THE SECRETARY'S REPORT.

[*Presented at the Stated Meeting, September 15, 1886.*]

THE MITIS PROCESS OF PRODUCING WROUGHT-IRON AND STEEL CASTINGS.

At the meeting of the British Iron and Steel Institute, held in May, 1885, Mr. T. Nordenfelt exhibited a remarkable assemblage of specimens of castings made by the direct melting of wrought-iron, which attracted much attention. Great curiosity was manifested in regard to the method by which such results, hitherto impossible of attainment save by the method of forging, were obtained, and which at the time were affirmed to have been produced in Sweden by an entirely new method.

The radical nature of the invention will be understood by all who are familiar with the manipulation of iron and steel, when it is stated that in this process wrought-iron is placed in crucibles, melted, and poured into castings of any desired shape, without in any way changing the quality of the metal. The resulting castings are solid and homogeneous to a high degree; they are considerably stronger than the wrought-iron used in their production; and are flexible and weldable to a degree which it has hitherto been possible to attain only in the highest class of wrought-iron forgings.

In reference to the qualities exhibited by these products, the name "mitis," from the Latin, meaning soft, or mild, has been appropriately chosen.

The process depends upon the addition, to the raw materials employed, of an exceedingly small percentage of another metal, which has the effect of causing an immediate and considerable lowering of the melting-point of wrought-iron employed in the operation. The melting-point of wrought-iron is so high that, even were it possible to obtain in furnaces a heat sufficiently intense to effect its fusion, and with sufficient superheating to permit of casting it in moulds before chilling, the metal is rendered quite worthless by the absorption of the furnace gases, as is demonstrated in the Bessemer process In this operation, the metal at the end of the first blow of the charge is substantially a completely

decarbonized iron, but is utterly worthless for practical uses, principally because of the gases it has absorbed, and which are eliminated in the after-blow by the action of certain admixtures, but with the result of producing a radical change in the nature of the metal, which is no longer wrought-iron, but a mild steel.

Having these difficulties in mind, the inventors of the mitis process, sought for a method of effecting the necessary superheating of wrought-iron without raising the temperature above the melting-point, and, paradoxical as the assertion appears, this is substantially what they have succeeded in doing. In the mitis process, the inventors have taken advantage of the fact, which holds good in many cases, that the alloys of metals melt at a lower temperature than the mean of their constituents. This peculiarity is exhibited in the most pronounced manner by the so-called "fusible metals." These are composed of varying proportions of tin, bismuth and lead, the melting-points of which are respectively at about 440°, 500° and 600° F., while the melting-point of a mixture of equal parts of these metals is at 254° F., or slightly above the temperature of boiling water. The addition of carbon to wrought-iron exercises precisely the effect which is desired, but unfortunately for the purpose in view, the character of the metal is changed, and steel or cast-iron is the resulting product.

To come directly to the point, it was found that the addition of aluminium to wrought-iron produced a very pronounced effect in the desired direction; and, also, that the quantity of aluminium necessary to be added to produce the desired effect is so small that it has no noticeable influence on the desirable qualities of the iron.

Speaking of the method at a recent meeting of the American Institute of Mining Engineers, Mr. Östberg said: "It is of this property of aluminium that we avail ourselves. We heat the wrought-iron just to melting, but not more; and then, as soon as the metal is melted, we add a small quantity of aluminium—from 0·5 to 0·1 of one per cent., thereby producing a sudden lowering of the melting point, and obtaining a superheating of say 300°, 400° or 500° F.—sufficient, at least, for our purpose, to be able to handle the metal in a practical way and pour it into castings." After the accuracy of this interesting observation had been fully verified, experiments were at once undertaken, with the view of ascertaining whether there were other substances besides alumi-

nium that would bring about the same result. These experiments included trials with "every conceivable metal, metalloid and alloy," with the result that nothing else would answer the purpose.

While the essential element of the mitis process resides in the addition to molten wrought-iron of a fractional percentage of aluminium, the successful practical working of the process appears to depend in a great measure upon the manner in which the several details of the operation are conducted. The more important of these, as named by Mr. Östberg, are, the selection of a suitable raw material; the possession of an effective form of furnace for melting the metal without injury; the proper handling of the metal from the time it is ready in the furnace until it is poured into the moulds; and the choice of a suitable moulding material. In respect to all of these details, the inventors claim to have made substantial improvements, which are essential to the successful manufacture of castings from wrought-iron or low-grade steel.

For the melting of the metal, a furnace has been designed in which petroleum, or its residuum, is employed as fuel, and which is described as being remarkably effective, both in respect to the enormous heating effect which it yields, and also in respect to the perfect control of the heats which it permits. These furnaces are so constructed that their operation is continuous. The crucibles (which are worked in pairs), passing gradually from the coolest to the hottest part of the fire, until the charge is completely melted, a freshly-charged pair being introduced as the last pair is removed. From furnaces of this construction operated at the Swedish mitis works, eight to ten pairs of crucibles are drawn per day of twelve hours, the charge being in each case sixty-six pounds of scrap—a record which speaks for itself of the effectiveness of the heating plant.

A special moulding material has been devised, made of hard-burnt finely-ground fire-clay of good quality, and mixed with sugar or molasses as a binding material. This, it is affirmed, is sufficiently refractory to successfully resist, without fusion, the high temperature of the molten metal, and has no injurious effect otherwise on the quality of the castings. The surface of the castings produced is unusually clean, and quite free from embedded sand. The castings require no annealing, as is the case with steel and "malleable" castings, but are simply cleaned up by emery wheels,

or otherwise, and are ready for delivery. To enable the casting to be done with the greatest expedition, water moulds of special design have been devised; the metal is kept at its full heat in the pouring ladle by means of a surface blast of very hot gases, and a number of moulds are fixed around the circumference of a turn-table in such a manner that one mould can be filled after the other, as quickly as it is brought under the lip of the ladle, and the castings are at once taken out of the moulds, so that each mould is ready for refilling as it comes around again under the ladle.

Mr. Nordenfelt, in his paper before the British Iron and Steel Institute, pointed out several facts in connection with the product of the mitis process which are of special importance to constructors—namely, "as the iron runs so exceedingly free without large heads, and as it falls out of the moulds so easily, the method of mitis wrought-iron castings must tend to save labor to a very important extent; and we have already found that it enables us to considerably lighten and greatly vary designs—such as designs of machinery, etc.—as we can, without extra cost, shape our moulds so that we give the strength of the metal where wanted, but only where wanted, whereas in forgings it would often not pay to complicate the shape. This method also enables a constructor to make *much bolder designs*, and of more different forms, knowing that such designs can be easily and cheaply carried out. Here, again, we find great advantage in being able easily to *weld the castings*, as we can cast the parts, which would otherwise be difficult to forge, or which would require much machinery, and weld them on to a bar or rod, as required."

The simplicity of the process above described, the certainty with which it can be operated, the uniformity of the product, and its good qualities in respect to strength and ductility, indicate an extended field of usefulness for it. The most difficult forms have been successfully produced in mitis castings, such as pulleys, smoke-consumers, wheels, knees, bends of piping, etc., having the tensile strength of mild steel forgings, at but slightly greater expense than for castings of ordinary shape; and, it is claimed, that there is scarcely any form of forging which it would not be more advantageous to cast by this method. The mitis castings threaten to seriously incommode the manufacturers of malleable castings, for which they not only offer a perfect sub-

stitute, but one which, in respect to strength and ductility, are distinctly superior; while for many purposes mitis castings can be employed for which malleable castings could not be made. The mitis process has also been applied to the production of steel castings, and with promising results. In one of the methods experimentally tested, the steel castings were from wrought-iron scrap as raw material, with the addition of the proper proportion of cast-iron to bring the percentage of carbon to the point required for each special purpose. To enter into the details of the various qualities of the products obtainable by the mitis process, by varying the character of the raw materials, would unnecessarily lengthen my remarks, the purpose of which is simply to describe its general features and the wide range of its applicability as a substitute for processes at present in vogue. (W.)

GERMANIUM, A NEW ELEMENT.

The *Berichte* of the German Chemical Society lately contained a brief statement of the discovery of a new element, by C. Winckler, the following details of which will be interesting:

Weisbach lately found in the Himmelsfürst mine, near Freiberg, a mineral which he named argyrodite, and which, on analysis, yielded seventy-three to seventy-five per cent. of silver, seventeen to eighteen per cent. of sulphur, 0·2 per cent. of mercury, but the analysis always showed a deficiency of six or seven per cent. Winckler has discovered that this deficiency is due to the presence of a new element, for which he proposes the name *Germanium* (symbol, Ge). The new element closely resembles antimony, and in acid solutions gives a white sulphide, soluble in ammonium sulphide. When argyrodite is heated in a stream of hydrogen, it yields a black, crystalline sublimate, which melts to brownish-red drops. This is principally germanium sulphide, mixed with mercury sulphide. It dissolves in ammonium sulphide, and is re-precipitated by hydrochloric acid as a white powder, readily soluble in ammonia. When heated in a current of air, or with nitric acid, the sulphide yields a white oxide, which is not volatile at a red heat. This oxide is soluble in potash. The oxide and sulphide can both be reduced by heating in a current of hydrogen, and yield the element as a gray, moderately lustrous substance, which is only volatile (without previous fusion) at a full red heat, and

therefore much less so than antimony. The volatilized element is deposited on cooling in small crystals much resembling those of iodine. When germanium, or its sulphide, is heated in a current of chlorine, the easily volatile white chloride is formed, soluble in water.

Winckler considers germanium as the element indicated by the periodic law as probably existing between antimony and bismuth He is now engaged in determining its atomic weight. (W).

BOOK NOTICES.

Some Features of the Recent Earthquake.

The above caption appears at the head of an article, by Mr. McGee, in *Science*. of September 24th. He begins by describing the "coastal plain" about Charleston, which is thirty or forty feet in altitude and diversified by "broad, irregularly meandering and inosculating troughs;" the higher parts being "naturally forested." It is a "slightly accented" topography. The geologic structure is remarkably simple (or will be when the formations are thoroughly studied); though the superficial stratum is "obscurely stratified." Beneath this member a stratum "contains sulphurets and various salts, either free or quickly liberated on oxidation." This phrase is not clear. If the stratum and its contents were oxidized, it would no longer contain sulphurets, and if anything were oxidized in such a stratum, it would be the sulphur in the sulphurets. Its precise thickness is not known, owing to depressions in the "subjacent surface" and from the impossibility of separating it from the "superjacent member." No satisfactory explanation is given of how a part could be at the same time "surface" and "subjacent." The "superjacent" sands are sometimes replaced by an "estuarine alluvium." The phosphate beds are "underlain by petrographically similar cretaceous deposits, increasing in heterogeneity somewhat downward to 2,000 feet," but some reasons favor the supposition that a "considerable thickness of cretaceous strata are infraposed." Of the phenomena it is said "the effects of the earthquake are themselves no more conspicuous than the indications of inequality and intensity" of the disturbance. Amongst the observations are mentioned "simultaneity of detonations with tremors."

The predominant effects of the shock of August 31st, are: "*first*, fissuring of the surface of the earth; and, *second*, crushing of foundations and chimneys, together with, *third*, slight displacement in different directions (and sometimes torsional) of buildings." The italics are Mr. McGee's own, but they do not quite give this thought lucidity. Further on we are told that "the architecture of Summerville is characteristic," but we are soon relieved of the necessity of puzzling over this singular fact and seeking to account for it by the hypothesis of a prehistoric settlement by buccaneers on reading a description of a most commonplace method of building which one may observe anywhere in the

South. Mr. McGee safely concludes that the sound of the detonations came "directly from the earth," but adds (as if this were too daring a statement to pass unqualified) "either as sonorous vibrations, or as soundless pulsations of such a period as to be converted into sound-waves on passing from earth to air." Ten Mile Hill, half-way between Charleston and Summerville, developed "craterlets" and "crateriform" orifices. "These crateriform orifices are now surrounded by their solid ejecta in annuli attenuating peripherally." It is likely that Mr. McGee means to say by this ornate sentence, that there are rings of dirt around the holes through which the water spouted. The water, we are told, was "extravasated," which suggests the "black eye" that industry received; and he records with some astonishment that it smells still of "sulphuretted hydrogen," although the quake is so long past. In all cases of "personally observed and well-authenticated compressive distortion, the kinks occurred in the low grounds." (He is speaking of railway rails.) Of the monuments in the cemeteries, "many have suffered torsional displacement, but of these some have turned with others against the sun; while others are displaced laterally without overthrow." He leaves the reader to picture this state of things, if the reader can. A picture of a "Charleston chimney twisted with the sun" is referred to. His conclusion is that "inferences as to the azimuth of the wave-paths in Charleston are premature."

We should think, from a perusal of his article, that they were! Nevertheless, "there are large areas within which the intensity of the disturbance culminated." This would seem to imply that in other areas the intensity of the disturbance was going on just as usual. Also, "within these areas," first referred to, there "are foci or nodes of maximum vibration, circumscribed and separated by annuli in which the vibration was less severe." Whatever may be the light which Mr. McGee claims to have shed on this very interesting and distressing phenomenon (and we do not see that it can be much), we may certainly credit him with adding to the English language more words than have been contributed by all American authors put together. His style, too, is really and truly his own. William M. Evarts might envy his sesquipedalian words, were they strung together so as to present a picture to the mind: but in this latter particular, it must be confessed that Mr. McGee is not in danger of being confounded with the eminent New Yorker. In this connection, it may be recalled that on the day after the earthquake the country was informed, through the Associated Press correspondent at Washington, of some marvellously clever observations made by Mr. McGee at Washington while the tremor was going on. It seemed a wonderful instance of presence of mind and fertility of resource, that on the occasion of an unexpected earthquake—(for it has nowhere been suggested that Mr. McGee was aware that an earthquake was about to come off)—a whole half column of "seismographic observations" should have been made. A tumbler of water (we were told) acted as an admirable seismograph to indicate the direction from which the waves came; while the "amplitude of the oscillation was readily ascertained by the swinging of the six-foot head-board of a bed." To one not so full of imagination as Mr. McGee, the history of that night would have probably been told in this simple statement—"I was in bed read-

ing when the earthquake came, and, noticing that the head-board of the bed rocked considerably, I jumped up, and observed even the water in the tumbler on my night-table quivering."

The results of his observations in and around Charleston are similarly simple when extracted from the ponderous verbosity in which they are enclosed. Thus: (1.) The geology of Charleston is clear when you know it. (2.) The shaking upset and twisted large objects all over the region from Charleston to Summerville. (3.) Holes were formed out of which water, mud, etc., were thrown. The odor of rotten eggs was noticed and is noticed still in places. (4.) It looks as if the motion at Summerville was more vertical and that at Charleston more horizontal, but it is doubtful if I would have thought of this if Prof. Milne had not mentioned it as characteristic of the central regions of disturbance of the Japanese earthquakes which he in a commission of the British Association has been studying for some years. (5.) Neither I nor anyone whom I have been able to find knows much about either the cause or the more detailed history of the convulsion. This statement is what one extracts from the report after reading eight columns of *Science*, with the necessary general philologic preparation to penetrate the lavish paint of thought and word. Do you ask why one should not furnish the public with this simpler pabulum, which would be so much more easily digested and take so much less time to swallow? What would become of the Government printers if one did not call the "tide marshes" of South Carolina "inosculating troughs?" And how would that pleasing industry to the rural Congressman, the shipment of "pub. docs.," be maintained? But this kind of thing degrades science, and teaches the uneducated public to look upon the scientific bureaux as word-mongering establishments.

THE WATCH AND CLOCKMAKERS' HANDBOOK, DICTIONARY AND GUIDE. By F. J. Britten. Sixth Edition. London: W. Kent & Co., Paternoster Row New York: E. & F. N. Spon, 35 Murray Street. 1886.

We had occasion to speak of the excellency of this work in this JOURNAL when its fifth edition was presented. How well the encomiums of this work then expressed were deserved, is shown by the short time in which a sixth edition is called for. Nor is this new edition a mere reprint of its predecessor. It has, on the contrary, valuable additions in text and illustrations, that bring it up to quite recent date in the science and arts connected with horology. So, for example, we find an illustrated description of the single three-legged gravity escapement of Dr. Leonard Waldo, published but a few months since in the *Horological Journal*. In his "Notes to the Sixth Edition," the author says: "In obedience to the request of several correspondents, who desired to use this work as a guide in setting out the escapements most generally used, I have added drawings where needed for the purpose. Other suggestions have also been met by the introduction of new matter, an index, and separate alphabetical lists of the French and German equivalents. Much of the book has been rewritten to bring it up to date, while descriptions of many useful tools and devices of recent inventions

are here published for the first time." This, we think, refers very modestly to the many valuable additions and changes this useful book has received in its new edition, which required an enlargement of seventy-two pages.

L. H. S.

Reports of the Committee on Indexing Chemical Literature. Dr. H. Carrington Bolton, Reporter. From the *Proceedings of the American Association for the Advancement of Science*, Vol. XXXIV. Ann Arbor Meeting, August, 1885. Read before the Chemical Section A. A. A. S. August, 1886.

These reports, which cover a little less than twelve pages, have the impress of care, as do all of Prof. Bolton's communications. It will be seen that of the myriads of chemical compounds now known, and of the many which are in hand, only four are published, viz.: petroleum, iridium, uranium, melting and boiling points. Four are reported as in progress, viz.: carbon monoxide, by Prof. W. R. Nichols, since deceased, explosives, meteorites and common salt. Nine are projected, viz.: specific gravity tables, chemical synonyms, milk analysis, a continuation of petroleum, chemical patents, aluminium, gems, scientific bibliographies and copper. Prof. Bolton appends an instructive little note on the needs of abbreviations and the defects of the various methods employed in recording scientific journals.

Prof. Bolton prints in the *Transactions New York Academy of Science* an interesting lecture experiment, showing the properties of potassium and sodium peroxides to a class by dropping the respective metals into their melted nitrates. He warns intending amateur experimenters against trying the same reaction in melting potassium chlorate without previously providing themselves with insurances on their lives and houses.

American Journal of Mathematics.

The lectures now being delivered at Oxford by Professor Sylvester on his "New Theory of Reciprocants," will appear in the coming numbers of the *American Journal of Mathematics*.

The lectures are presented in quite simple style, and will be exceedingly interesting to all students of the modern algebra, or, more accurately, of the theory of invariants. The first eight or nine lectures will appear in the forthcoming number of the *Journal*, Vol. VIII, No. 3.

Anhydrous Chromic Acid.—M. H. Moissan gives a simple method for purifying chromic acid from sulphuric acid, and states the action of anhydrous acid upon several simple bodies. Oxygen and ozone are not affected. If a mixture of chromic acid and sulphur in excess is heated, they combine with a very brilliant light, forming a brilliant lecture experiment. As soon as phosphorus and chromic acid meet, under proper conditions of heat, there is an explosion and incandescence. On heating a mixture of dry chromic acid and arsenic, there is a combination with brilliant light. Chromic acid when melted and maintained at a temperature of about 200° violently attacks the metals which are easily oxidized. With sodium there is an explosion with great heat and light.—*Ann. de Chim. et de Phys., Aug., 1885.*

PROGRAMME OF LECTURES FOR THE SEASON 1886–87.

The following Lectures will be delivered during the coming winter, viz.:

1886.

Nov. 15, PROF. PERSIFOR FRAZER, D. SC., FRANKLIN INSTITUTE, "Elements of Chemistry."

" 19, MR. E. A. GIESELER, C. E., Superintendent of Construction, Fourth Light-house District, "The Illumination of Maritime Coasts."

" 22, PROF. FRAZER, "Elements of Chemistry."

" 26, MR. J. LUTHER RINGWALT, Editor of the *Railway World*, "From the Trail to the T-Rail."

" 29, PROF. FRAZER, "Elements of Chemistry."

Dec. 3, MR. RINGWALT, "From the Travail to the Train."

" 6, PROF. FRAZER, "Elements of Chemistry."

" 10, MR. F. LYNWOOD GARRISON, F. G. S., Philadelphia, "The Microscopic Structure of Iron and Steel."

" 13, DR. N. A. RANDOLPH, Biological Department, University of Pennsylvania; Editor of the *Medical News*, "Life and Death."

" 17, PROF. CLEVELAND ABBE, Army Signal Office, Washington, D. C., "Popular Errors in Meteorology."

" 20, DR. RANDOLPH, "Thought and Sleep."

1887.

Jan. 3, MR. C. HANFORD HENDERSON, Instructor in the Manual Training School, Philadelphia, "The Bessemer Steel Process and its Modifications."

" 7, MR. EDWARD ATKINSON, Boston, Mass., "The Growth of Manufactures in the U. S. considered as a Social Problem."

" 10, MR. HENDERSON, "Glass-Making."

" 14, PROF. CHAS. F. HIMES, PH.D., Dickinson College, Carlisle, Pa., "The Stereoscope and its Applications."

" 17, MISS HELEN C. DES. ABBOTT, Philadelphia, "Plant Chemistry as an Applied Science."

" 21, MR. WILFRED LEWIS, M. E., with Wm. Sellers & Co., Philadelphia, (Subject to be announced).

" 24, MISS ABBOTT, "The Chemical Basis of Plant Forms."

" 28, MR. JOHN HARTMAN, of Taws & Hartman, Philadelphia, "The Crucible of the Blast Furnace."

" 31, PROF. FRANCES EMILY WHITE, M. D., Women's Medical College, Philadelphia, "Hygiene."

Feb. 4, MR. JOHN BIRKINBINE, Philadelphia, "Rainfall and Water Supply."

" 7, PROF. J. BURKITT WEBB, Stevens Institute of Technology, Hoboken, N. J., "Mechanical Paradoxes."

Feb. 11, Mr. Carl Hering, Electrical Engineer, Philadelphia, "Electricity: The Different Forms in which it Manifests Itself."
" 14, Prof. White, "Hygiene."
" 18, Mr. Hering, "The Electrical Transmission of Energy."
" 21, Mr. Wm. F. Durfee, M. E., United States Mitis Company, New York, "Hero of Alexandria and the Arts and Mechanism of his Times."
" 25, Prof. L. d'Auria, U. S. Hydrographer, Philadelphia, "Some Peculiarities of Tidal Rivers, with Especial Reference to the Delaware River."
" 28, Mr. C. O. Mailloux, Electrical Engineer, Brooklyn, N. Y., "The Storage of Electrical Energy."
Mar. 4, Mr. Birkinbine, "Iron Smelting in the United States."
" 7, Commander J. R. Bartlett, Chief of the Hydrographic Bureau, U. S. N., Washington, D. C., "The Physical Geography of the Sea."
" 11, Capt. Otho Ernest Michaelis, U. S. A., Watervliet Arsenal, W. Troy, N. Y., "The Army of Kukuanaland."

Franklin Institute.

[*Proceedings of the Stated Meeting, held Wednesday, October 20, 1886.*]

Hall of the Institute, October 20, 1886.

Vice-President Chas. Bullock, in the Chair.

Present, 152 members and sixteen visitors.

Additions to membership since the previous meeting, four.

The Secretary reported the following recommendations from the Committee on Science and the Arts, viz.:

The *Elliot Cresson Medal* to Mr. Hugo Bilgram, of Philadelphia, for his "Bevel-Gear Cutter;" and to the Pratt & Whitney Company, of Hartford, Conn., for their "System of Interchangeable Gears."

The *John Scott Legacy Premium and Medal* to Philip J. Grau, of Philadelphia, for his "Improvement in Feed-Water Purifiers;" Cyprien Chabot, of Philadelphia, for his "Method of Forming Bevelled Rims on Watch-Cases;" and Hugo Bilgram, of Philadelphia, for his "Bevel-Gear Cutter."

The above-named recommendations were severally approved, and the Secretary was directed to take the usual measures in the premises.

The Special Committee on Reorganization reported the following resolutions, with a recommendation that they be adopted, viz.:

"*Resolved*, That the chairman be authorized to increase the number of the committee, at his discretion.

"*Resolved*, That the committee be authorized to solicit subscriptions for the purpose of purchasing a site, and for the erection of new buildings suitable for the enlarged work of the Institute.

"*Resolved*, That when *bona-fide* subscriptions, amounting to $100,000,

shall have been obtained, the committee shall be authorized to contract for a suitable piece of real estate."

The resolutions were unanimously adopted. The Secretary presented the following:

At a conference of the officers of the United States Signal Office and the Committee on Meteorology of the FRANKLIN INSTITUTE, held Tuesday, October 19th, to consider the feasibility of establishing a State Weather Service, the following was unanimously adopted:

Whereas, The FRANKLIN INSTITUTE ceased the direction and management of meteorological observations in the State of Pennsylvania, because of the establishment of a National Weather Bureau, and

Whereas, It is believed that the time has arrived when the INSTITUTE may largely aid the people of this state and the United States Signal Service in disseminating their forecasts and weather statistics, collect climatic and other data that will be of much importance to our agricultural, manufacturing and commercial interests; therefore, it is resolved by this meeting, to recommend to the INSTITUTE the passage of the following resolution:

"*Resolved*, That the subject of organizing a State Weather Service be referred to a special committee, to be appointed by the President, with the request to report a plan for the same to the stated meeting in November."

The resolution was adopted.

The Secretary reported the receipt of a communication from Mr. P. B. DELANY, of New York, and at present in Berlin, in reply to the protest of Mr. PAUL LACOUR, of Copenhagen, referred to in the proceedings of the September meeting.

On motion of Professor Houston, a special committee was appointed to inquire into the respective merits of the claims of Messrs. LaCour and Delany, with instructions to report as early as possible. The Chairman appointed Mr. E. Alex. Scott, Prof. E. J. Houston, Mr. W. W. Griscom, Mr. Alex. E. Outerbridge, Jr., and Dr. Wm. H. Wahl, to constitute the committee.

Mr. W. M. SCHLESINGER, of Bradford, Eng., then read a paper on "The Schlesinger System of Electric Transmission," with an account of the trials of the same, on the line of the Ridge Avenue Passenger Railway Company. The paper, with discussion thereon, appears in the November impression of the JOURNAL.

Mr. WM. F. DURFEE, of New York, by special invitation, gave an interesting description of the process of making "mitis" castings of wrought-iron and steel. Mr. Durfee illustrated the subject by means of a diagram of the melting furnace employed, and by the exhibition of a number of characteristic specimens.

The Secretary's Report embraced an account of certain evidences of earthquake action near Haddonfield, N. J.; a description of the Castner process of producing the metals of the alkalis; a statement of the comparative production of iron and steel in Great Britain and the United States in the first half of 1886; and the exhibition of interesting specimens of composite photography, made by Mr. W. Curtis Taylor, and of isochromatic photography, by Mr. Fred. E. Ives.

The meeting was then adjourned. WM. H. WAHL, *Secretary*.

THE "NOVELTIES" EXHIBITION OF THE FRANKLIN INSTITUTE, 1885.

ABSTRACTS OF REPORTS OF THE JUDGES.

(*Continued from page 320.*)

GROUP II*g*.—STEAM-HEATING AND VENTILATION.

Judges:—William Vollmer, *Chm.;* C. S. Schwenk, C. E., M. D., M. R. Mucklé, Jr., F. B. Paist, S. M. Vauclain, Coleman Sellers, Jr.

E. C. TAINTER, PHILADELPHIA.

The Cooper Steam Generator.—Has a boiler for furnishing hot-water or low-pressure steam, and is applicable for heating dwellings or green-houses with steam or hot water for various laundry, dairy, farm and other operations requiring steam or hot water, and even for driving light machiney.

The fire-pot or furnace is in the form of an inverted frustrum of a cone, terminating in a large smoke-flue: around this fire-pot is an outer shell, which is of similar form. The space between these two cones forms the water-space, and a curved top bolted to the outer shell forms the steam-space of the boiler.

The charging-door is in the smoke-stack or flue, and a separate internal passage leads the coal to the centre of the fire-pot. The lower part of this internal coal-chute or "self-feeder" is surrounded by a coil of pipe, having a top and bottom connections with the water-space. This coil affords additional heating-surface, assists in promoting circulation, and, as it never becomes red hot, it is said to prevent the coal in the "feeder" from being burned before it reaches the fire-surface. The principal parts of the generator are cast-iron, and it can be readily taken apart if desired.

Two joints are packed with copper-wire, and it is claimed that if a leak should occur, it is readily stopped by caulking this wire.

A self-feeding supply-valve, operated by a float, admits water as needed, and a glass water-gauge, a steam-gauge and a safety-valve are also provided. The self-feeder is said to hold coal enough for ten or twelve hours. When used for steam-heating, the generator is provided with an automatic damper-regulator to control the draught.

If water cannot be obtained under sufficient pressure to feed the boiler, a barrel or cast-iron tank, set sufficiently high up, will answer the purpose.

The makers claim for the generator: moderate first cost, no brick-work or foundation, absolute safety, ease of operation, reliability and great heating capacity.

For cheapness, efficiency and ease of operation—

(*A Silver Medal.*)

JAMES SHORE, PHILADELPHIA.

The Germantown Open-Grate and Hot-Water Apparatus.—Combinations of hot-air and steam-heating and hot-air and hot-water heating devices are common, many being in use at the present time. Mr. Patton's apparatus combines the advantages of an open fire-grate, with a hot-water heating system for the rest of the house, in which it is placed. In appearance, it is like the ordinary open-grate, with the sides and back of the fire-place serving as one of the walls of a water-chamber, similar to the water-back in the range, and arranged in such a manner as to absorb the greatest amount of heat from the fire. Radiators or pipe-coils can be placed in rooms on the same floor where the grate is stationed, or on the floor above. The radiators or coils of pipes are connected to top and bottom of the water-chamber, surrounding the grate, and the whole system filled with water, will heat the rooms in which the radiators or coils are placed, the water as it cools returns to the bottom and is replaced by hot water from the top of the water-chamber. A reservoir, placed at the highest point of the system serves to keep the pipes, radiators and water-chambers full of water, and free from air, as is usual in all hot-water heating plants. In addition to the advantages of heating a house with an open-grate and hot-water, the inventor claims that a thorough system of ventilation can be obtained in connection with this apparatus, in the following manner:

The pipes leading from the water-chambers are carried through the smoke-flue of the grate to the highest point where heat is required. The outlets and returns from these pipes to the radiators or coils enter the rooms close to the floor, an opening of an inch or two is left around the pipes coming through the wall, which serves as a means of drawing the heavy air, which falls to

the floor, from the room and into the smoke-flue. This is replaced by fresh air from the windows and doors.

The room in which it is placed is thoroughly ventilated at the fire-place.

To induce additional circulation in the room in which the grate is placed, and to make use of the heat given off by the cast-iron frame, a small flue is cast on each side of the fire-place, adjoining the water-chamber and part of the main casting.

These flues extend to the top and front of the frame, and have openings provided with registers close to the floor.

In the grate exhibited, no provision has been made for removing the scale and sediment, which may accumulate in the water-chamber, and which at times makes inoperative the ordinary range water-back.

For novelty and efficient combination of open-grate with hot-water heating system— (*A Bronze Medal.*)

BROGAN & SMITH, PHILADELPHIA.

Heating Apparatus.—A combined hot-air and water apparatus for heating buildings, especially those which are too large to be easily warmed by one furnace.

This apparatus consists of a cast-iron base, supporting a conical furnace, over which a short vertical flue boiler, covered by a wrought-iron smoke-box, which is connected with two or more sheet-iron drums.

The products of combustion pass through the boiler, heating the water, and thence to the chimney. The whole device is enclosed by a galvanized-iron case, which forms a hot-air chamber, and gives the apparatus the general appearance of an ordinary portable-heater.

The boiler is tapped for pipes, by which the hot-air is carried to the radiators, situated under the more distant flues, and the rooms above are thus heated by indirect radiation.

The hot-air from the air-chamber is conducted in the usual manner to the more adjacent flues. A cast-iron tank, with float-valve and gauge-glass, indicates the height of water in the boiler, supplies the water necessary to keep the system always full, and allows for expansion.

The furnace is provided with a shaking-grate and dumping arrangement, worked conveniently from the outside.

The apparatus is commendable as an ingenious combination of two well-known systems of heating, and for its thorough utilization of the heat of the fire.

A. PENROSE BENNER, PHILADELPHIA.

Philadelphia Manifold House-Heater—Is so arranged that the air may be heated by one furnace for each room of a building, and conveyed thereto by separate pipes leading from the furnace.

The furnace is provided with the necessary ash-pit, doors, dust- and smoke-flues and other appurtenances ordinarily found in furnaces for this purpose, and the whole is inclosed in brick-work.

The heaters are made of wrought-iron, not thinner than fourteen gauge, and are closely riveted at the joints to prevent leakage of coal-gas into the heater.

They are suspended within the brick-work by irons riveted to the heaters and built in the brick-work, respectively, and are arranged in a convenient manner, whereby to make the best disposition of the space and to admit of a free circulation of heat and the products of combustion from the furnaces around and among them.

The smoke passes from the furnace to the stack at the upper part of the brick-work, except when the fire is first started, when a damper may be opened into the dust-flue to increase the draught.

Arranged around the fire-box is a common cold-air receptacle, which forms part of the fire-box. Fresh air is admitted to the receptacle through flues.

The base of each wrought-iron heater is connected by a neck to this receptacle. A vapor-pan is placed at each side of the fire-box for moistening the air.

The upper portion of each heater is connected with a tight hot-air distributing flue, which leads to the apartment to be heated. The operation of the apparatus is as follows: The fresh air enters the receptacle through the flues, and passes through the separate heaters, which are exposed to the fire, and thence escapes through the separate distributing pipes into the several apartments to be heated. Thus each apartment is heated independently, and a room on a high floor cannot rob one on a lower floor of any portion of the heat intended for it.

In the apparatus exhibited, instead of carrying heated air by separate pipes to individual rooms, each heater of the system, at

its upper part, connects with a general air-space, situated under the roof of brick-work enclosing the furnace.

This space or reservoir of hot-air is tapped, as may be desired, with pipes, conducted to the several apartments to be heated.

THOS. H. HOLMES, PHILADELPHIA.

Newton's Steam-Trap.—An objectionable feature of this trap, in our opinion, is the hinged cock, or connection from steam-pipe, which is liable to be a source of trouble.

We recognize the efficiency of the trap at the expense of considerable steam, and the mechanism is liable to get out of order.

(*Honorable Mention.*)

A. J. KOCH, PHILADELPHIA.

Barry's Steam-Trap.—This trap, although not meeting the Judges' views as to what a thoroughly reliable and economical steam-trap should be, has, we think, several points of marked excellence.

By the ingenious device employed, the water is effectually removed, and at the device the same time precludes any waste of steam. For novelty and simplicity of action—

(*A Bronze Medal.*)

THE PHILADELPHIA EXHAUST VENTILATING COMPANY, PHILADELPHIA.

Blackman Exhaust-Wheel or Blower.—The following distinctive merits are claimed for this device, *i. e.*, it exhausts or blows a large amount of air with a given power, than any other air-moving machine, because of the peripheral flange or end buckets peculiar to this wheel. Has a large feed-area, and will give a larger amount of pressure than any other fan.

Will run in any given position, without a change in bearings or supporting-frame.

In *drying*, its superiority is unquestionable, and its value as a ventilator is apparent.

For general excellence— (*A Silver Medal.*)

J. HENRY MITCHELL, PHILADELPHIA.

Smith & Caldwell Ventilating-Fan.—This has a regulator for

regulating the circulation of air. The regulator is simple and can be easily operated, while the fan is in motion, by means of the regulator. The blades can be so adjusted as to give a strong or gentle circulation, or the circulation can be dispensed with entirely, or it can be made to blow upwards.

For a regulator, by which the position of the blades may be adjusted while in motion— (*A Bronze Medal.*)

HALL & CARPENTER, PHILADELPHIA

Buckeye Revolving-Ventilator—Embraces the combination of a conical and funnel-shaped deflector at the windward end of the hood, the effect of which is to concentrate the force of the wind on the space between the two, and the series of small openings in the upper part of the space, the result of which is a series of sharp air-jets acting upon the ascending column of smoke or hot-air in the most advantageous place, and the most effective manner.

The triangular form of the exhaust end of the hood, the result of which it is claimed is to cause the hood to move readily with the wind, and to pass out the hot-air or smoke with an upward ease, and with less horizontal deflection.

(*Honorble Mention.*)

HALL & CARPENTER, PHILADELPHIA.

Moore's Ventilator.—This cap to a chimney is supposed to act as an outside suction ventilator.

The band is its especial feature, and for this it is claimed that it is so placed as to afford thorough protection from storm, while at the same time it does not clog the delivery, but tends, under pressure, to create a vacuum, and thereby accelerate the motion of the air from the pipe.

E. C. TAINTER, PHILADELPHIA.

Mayer's Radiator.—This possesses large radiating surface in proportion to the volume of steam contained.

It is made in convenient forms, and is especially adapted for use with cold-air flue from the outside.

The device, in our opinion, seems deficient in means for removing air from the tops of the tubes and in providing for thorough circulation.

JOURNAL

OF THE

FRANKLIN INSTITUTE

OF THE STATE OF PENNSYLVANIA,

FOR THE PROMOTION OF THE MECHANIC ARTS.

VOL. CXXII. DECEMBER, 1886. No. 6.

THE ELECTRICAL EXHIBITION AND PURE RESEARCH.

BY M. B. SNYDER, Professor of Astronomy, Central High School, Phila.

[*A Lecture delivered before the* FRANKLIN INSTITUTE, *February 8, 1886.*]

When requested to develop before the INSTITUTE, some topic relative to the late Electrical Exhibition, it occurred to me that there was at least one line of reflection it were well to insist on, before the memory of that brilliant display should fade too deeply. There were those who had reported upon the uses and peculiarities of the special exhibits. There had been full account taken, as well of the praiseworthy inventive and mechanical skill displayed as of the immediate practical bearing of the several inventions. There had even been attempted practical tests which should haply add to the commercial recognition and credit of the inventor.

But what should be said if in our Exhibition, we failed to recognize anything more than the genius which presides over mechanisms and patented devices; if, through thoughtlessness or neglect, we ignored that great body of unregistered exhibitors, who, by their researches alone, had given silent though effective

tribute. It seemed to me that even America, with all its worship of the immediately practical, and with all its bold faith in haphazard progress, could well afford, as for a moment it cast a last look upon its first great electro-technical exhibition, to do homage to those far-seeing minds, who in this field had made invention possible and progress a necessity.

I propose then that the thread of our reflections shall be the dependence of the Electrical Exhibition upon pure research. And, to prevent misapprehension, I desire that the words "pure research" should be understood to imply that class of scientific work which means investigation for the sake of the beauty of truth and fact, though the applications and the mercenary rewards be never so remote; that holds the advancement of the borders of knowledge under the impulse of an unmeasured faith in the eventual advantage to be its highest, noblest aim. It should, however, not be inferred that antagonism to the so-called "practical science" is intended, except in so far as that name is a cloak for empiricism. Indeed, it would be folly at this stage in the history of any science to moot a distinction between the workers in theory and the workers in application, seeing that it is now well understood that the very highest efforts in each field are only attainable by a just recognition of the claims of the other. We know well that one theory may comprehend a thousand applications and that one appliance may demand a score of theories. Research and practical application are infinite debtors, the one to the other. And yet the habitual neglect of the claims of the former in our new civilization, is sufficient reason for limiting our attention to research as having so richly contributed to our present practice in electricity.

In addition, however, to the motives already indicated, I should mention at least two others as urging to this line of thought. The first is: The blank discouragement and almost insuperable difficulties encountered by the American student, who may aim to further research for its own sake; the second: the pressing necessity for establishing in our midst foundations whose chief aim shall be the advancement of physical research, and the indoctrination of its results into the public mind. To these points, I shall now and again refer.

For if we could show but a little more clearly how the great practical operations exhibited, are the direct result of the past

study of experimental and theoretical science; if we could show that all the great inventions presented to our view drew their very existence from the paitent and faithful investigations of men engaged in pure reseach, might we not entertain the fond hope that some more decided, some more earnest movement should be initiated to further that scientific spirit in our midst?

It would be useless to disguise the difficulty of making a statement of this dependence of the exhibited results upon pure science, that should deeply affect every mind. To the majority of spectators at the Exhibition, I have no doubt that the prominent impression was the beautiful spectacle realized by the inventor's skill. At most, the immediate practical result, was all this type of mind cared to appreciate. They may have been dazed and somewhat puzzled, but, it is to be feared, that to them the presence of the real presiding genius was never clearly disclosed. There are, however, others who glance through the great display with different eyes. To these are present the long array of experiments and theoretical investigations at the basis of many a single practical result. And again they recall a single experiment, which means ten thousand dynamos of a hundred different types. Let us then join this group as it studies the Exhibition and gather at least a few glimpses of the real origin of the important industrial display.

Our attention, as we enter, is for a moment arrested by the title: "The *International* Electrical Exhibition of the FRANKLIN INSTITUTE." Now the warmest admirers of the Exhibition admit that there was comparatively little in the way of foreign exhibits to warrant the title international. The quick succession in which such exhibitions had been held in Europe, and the consequent multiplied expense to exhibitors was undoubtedly the factor which prevented the full realization of the plan of the INSTITUTE. And yet, from a philosophical standpoint, the Exhibition could not be less than international. We shall, indeed, have to say that nearly all the great spirits in physical research, to whom we have to refer as contributors to the result, were nurtured by the European nations; and that it is to the enlightened encouragement of research abroad that this Exhibition owes most.

As we now glance over the character of the electrical display and note the deftness with which this strange form of energy

serves the purposes of our modern life—as we find electricity no more a mere plaything in the hands of a few scientists, but now the willing servant to a thousand and one earnest uses, we cannot but mark the severe contrast between this result and the unpromising beginnings.

Instinctively our imagination turns back to that early American time, when in or near the self-same locality there was to have been held another electrical exhibition. Strangely enough, we call this the Electrical Exhibition of the FRANKLIN INSTITUTE, while the other was an exhibition given by Benjamin Franklin himself. The marvellous demonstrations in electricity made at that exhibition must indeed have stirred the reflective minds of early Philadelphia as deeply as the wonders of our Exhibition could have affected any of us.

It seems that in a mild spirit of revenge upon the great difficulties encountered in developing anything of immediate use from his electrical experiments, and as a sort of semi-ludicrous, semi-earnest challenge to those who doubted the eventual utility of such high scientific pastimes, Franklin wrote of that earliest American electrical exhibition, the following prospectus which I shall reproduce with his own emphasis:

"Chagrined a little that we have been hitherto able to produce nothing in this way of use to mankind; and the hot weather coming on, when electrical experiments are not so agreeable, it is proposed to put an end to them for this season, somewhat humorously in a party of pleasure, on the banks of *Schuylkill*. Spirits at the same time, are to be fired by a spark sent from side to side through the river, without any other conductor than the water; an experiment which we some time since performed, to the amazement of many. A turkey is to be killed for our dinner by the *electrical shock*, and roasted by the *electrical jack*, before a fire kindled by the *electrified bottle*: when the healths of all the famous electricians in England, Holland, France, and Germany are to be drank in *electrified bumpers*, under the discharge of guns from the *electrical battery*."

We are happy to say that Franklin's dream of something "of use to mankind" from electrical research was fully realized at the recent Exhibition, held but a little more than a century after that of his own.

What a glowing picture should we have had from the ready

pen of the old statesman, could he, by some magic of the imagination, have been invited into the ideal studio of our modern exhibiting electrician. There he should have found an apartment decorated on every hand with the beautiful results of the electrometallurgic art, furnished with tables bearing a wealth of electroplate, with books, fine pictures and rare scientific drawings reproduced from electrotypes, with clocks strangely moved and controlled by electricity, with electro-chronographs recording to the utmost fraction the time of occurrences a hundred miles distant, with electric signal buttons ready to register both an audible and visible signal at points near or remote, with telephones that allow a conversation to be held at a distance of twenty miles as easily as with one's neighbor, with telegraphic sounders whose brazen hearts thump with messages that have travelled a thousand miles, with a mirror galvanometer whose delicate indications reveal thoughts that have held their tireless course through three thousand miles of ocean cable, with sphygmographs that record the frequency and the varying force of the pulse of the sick; with stock tickers telling the continuous story of the rise and fall in the pulse of the commercial world; with signalling devices that make police and fire departments, as well as a host of messengers, our house servants; with electric lamps shedding the soft radiance of daylight, and serving a score of uses, both useful and artistic; and finally, with electric-motors ready to move all sorts of machinery, or, if we choose to use the studio as a travelling-car, to speedily propel us from town to town by means of the mystical energy that may pass through a simple wire. All this and much more would have contributed to the contrast of the two periods of early experiment and later use.

If we should only regard the visible results, we might perhaps consider the lightning-rods attached to our Exhibition building as the only remaining indication of the early activity of Franklin and Kinnersley. But we must here insist on a deeper insight into the relations of effect with cause in electrical history. Franklin's chief glory consists in the fact that he was among the first to propound an explanation of electrical action; to clearly moot a theory which should thenceforth be used for the furtherance of experiment. If he was among the first to show experimentally "the wonderful effects of pointed bodies, both in *drawing off* and throwing off the electrical

fire," he was also among the first to take a broad survey of the whole problem of loss of electrical charge, and above all to propose to himself such a conception of the action of the "electrical fire" as should be applicable to every form of experiment.

All the way from the sixth century B. C., when Thales rubbed the *elektron* and noted its attractive effect on light bodies, down to the middle of the eighteenth century when Franklin and Symmer first stirred the scientific world by their theories of electricity, we note only, for the most part, isolated experiments. Gilbert, who first distinguished between magnetism and this force which he thence called electricity, had indeed essayed to explain the attraction of electrified bodies by the analogy of the melting together of two drops of water. Otto Guericke had discovered that electrified bodies also suffer repulsion and probably first had seen an electrical spark. Stephen Gray had distinguished between conductors and non-conductors, and had noticed the electrification of bodies by mere presence, by induction. Du Fay had proved that two distinct kinds of electrification might be excited by rubbing different substances, and that the one class of rubbed bodies attracted the other class of rubbed bodies while each repelled its own kind. Van Kleist had discovered what is now known as the Leyden phial, and Van Musschenbroek had made it famous among all the learned. Winkler had set fire to a number of inflammable substances by means of the electric spark, and many more curious results had been obtained. But futile, indeed, would have been these isolated experiments, if Franklin, and Symmer, and Winkler, and Aepinus, and Wilke had not set the world agog by a famous contest over the theory of electrical action.

Experiment was opposed to experiment and explanation to explanation in the sharp battle for truth between the unitarian and the dualistic theories of electricity. What matter if the contest between them has continued even to our own day, and the true nature of electricity be almost as much an enigma now as then. It has been the great unsolved problem that has stimulated research and incidentally brought about discoveries of the first magnitude. We learn here again, that the clear mooting of a scientific theory may have an immense influence on scientific and material progress, in that it provides an aim and suggests a plan for experimentation. Scientific history abounds with examples

which might be cited in illustration of this sort of stimulus to progress. You will allow me to divert your attention to an analogous and notable example in the history of astronomy.

When Copernicus found that the conception of the earth's motion around the sun accorded best with his observations of the positions of the planets, and he announced the bold hypothesis, it was opposed on the ground that if the earth moved in an orbit, the fixed stars should also appear to describe small movements on the heavens; in other words, we should be able to determine the parallax, and consequently the distance of the fixed stars in terms of the earth's distance from the sun. No such movement was observable in the stars, and Copernicus was obliged to assert that the stars were so distant and the displacement due to parallax so small that his measurements could not detect the motions. Here was the challenge to the improvement of the instruments and methods used in observing—a challenge which bore the richest fruit. Copernicus could determine stellar position within several minutes of arc, Tycho Brahé within one minute, Bradley within a second or two; and only when Bessel, in 1836, brought it down to tenths of a second, was the distance of a fixed star actually measured. The final proof of the justice of the Copernican statement concerning the immense distances of the stars was, however, by no means the main acquisition to astronomy. Tycho Brahé had laid the foundation for the discovery of Kepler's Laws, Bradley had discovered aberration and nutation, and astronomy had advanced to the point of refinement in the measuring process that made the discovery of the law of gravitation by Newton possible. But above all, delicate instruments had been invented and rigorous mathematical methods of observing had been devised, which should remain a rich legacy to physical science for all time.

Thus also in electricity were the arts of observation perfected, and the discoveries multiplied by a ceaseless desire to prove the correct conception concerning the nature of the electrical action. On the one hand, electroscopes, electrometers, unit jars and other devices for the qualitative and quantitative measurement of this force were devised by many. On the other hand, it was reserved for Tobias Meyer to suggest and for the great Coulomb to prove that electrical repulsion and attraction followed the rigorous mathematical law of decrease according to the inverse

square of the distance. These men were both able mathematicians, but Coulomb in addition made himself the father of electrical measurement by the invention and shrewd application of the torsion-balance, and you shall find that the great discovery he made, is fundamental to all electrical theory and practice. Ofttimes this law of Coulomb is hid by the later deductions and by the nearer rules of practice, but if you go back to fundamental conceptions you finally cast anchor in a little mathematical expression borrowed from that which states the law of gravitation. Thus, in the search for the true nature of electrical action, now an ingenious instrument, now a great law is discovered

It is here to be remarked that although all this was accomplished in electricity, generated by friction, we find scarcely any vestige in our Electrical Exhibition of this method of production. Indeed, I do not remember to have seen there a single instance of this method of producing electricity. And yet there, as constant reminders, stood the old historical machines and there the educational examples of the "balance à torsion" of Coulomb.

If, now, we seek out the sources of the electricity, used in most of the ordinary electrical appliances shown, and used particularly in connection with our devices for communicating thought to a distance, we shall find the voltaic battery silently furnishing a constant supply.

It was in 1790, that Galvani first announced the great discovery which led finally to the development of this new source of electricity. We will not, as has so frequently been done, place this discovery to the account of the mere accident of the twitching of frogs' legs, when touched by metal, as they lay near an electrical machine. That was undoubtedly the occasion of directing Galvani's attention to a new phenomenon; but we must not ignore the fact that Galvani, as a student of medicine, knew something of animal electricity and of electricity in general. For to his interest in animal electricity and to his bias in that direction, we must attribute both his closer study of the occurrence and his theory that the real seat of the electricity was in the nerves of the frog.

It was, however, to Alessandro Volta, that the greater credit was reserved of setting the whole matter in a clear light. Although his first work on this subject bore the title of *Animal Electricity*, he soon directed his attention to the contact of the metals as the

cause of the electrical disturbance. With the method of a trained physicist he ceased to use the frogs' legs as electroscope and showed that still the simple contact of two metals produced an electrical action. You remember the old experiments with two coins of different metals which might either produce an acid taste by contact in the mouth or a flash of light before the eye if it were included in the circuit. With this, Volta's investigation had but just begun. He called attention to the fact that, in this same experiment with the metals in one relation in the mouth the taste was acid, in another relation the taste was that of an alkali, and that moreover the taste *continued* without interruption so long as the contact of the metals continued. This we now recognize as the first glimpse of the chemical action of the electrical current. Intent on clearing up his contact theory of the production of electricity, he studied the effect of contact of various metals, arranged them in a series in which the middle terms might be removed with indifference, and proved that a current could only be produced when a liquid intervened in the series. He discovered the first form of what we now know as the voltaic battery. Everyone knows something of the classical contest between Volta's contact theory and the conception of the animal electricity of Galvani, as well as of that other greater contest between the Volta contact theory and the chemical theory of the battery. It required a Commission of the Institute of France, with such members as Laplace, Coulomb and Biot to give full recognition to the immense services rendered to science by Volta's labors.

It is interesting at this time to note that at least three lines of investigation diverge from the standpoint of Galvani and Volta. Galvani was absorbed in animal electricity, and among the number of experimenters who, with renewed vigor, took up this line of research could be reckoned Von Humboldt, who is said to have inflicted on himself a large and painful wound in order that he might study the relation of electricity to animal tissue under normal conditions. If medical electricity, so fully represented at the Exhibition by a variety of appliances, has any sufficient reason for its existence, it should have profited by these and a long series of similar researches that followed in Galvani's wake. On the other hand, Volta inaugurated a series of the most refined investigations on the potential of contact, and it is probable that no other

electrical question has developed more refined methods of experimentation. Although a brilliant line of physicists, from Volta to Sir William Thomson, discuss and experiment on the question, the mystery is still ours. The third direction given to investigation was, as you know, the chemical one, with its Ritters, its Davys, Becquerels and Faradays.

It would serve no useful purpose to recall the names of a tithe of the chemists and physicists who have step by step developed the voltaic battery as now used. Whether of one fluid or two fluids, of higher electro-motive force or of lower internal resistance, it matters not, the battery is the finished product of an hundred willing workers in the field of pure research.

No one who fails to recall the familiar history of electrical progress can have a just conception of the many and widespread ramifications incident to the introduction of the Voltaic method of generating electricity. We have only to pause before one of those large storage batteries of the Exhibition to be reminded of the early discovery by Ritter of the polarization of the voltaic cell, and the later developments of polarization, particularly in the hands of Planté, into a factor as useful as it was once inimical. This is but an instance, and very briefly stated, of many lines of research suggested by the battery. We mention next the galvanoplastic processes so rich in utility and beauty, as due to the study and use of the battery in electrolytic action, by Faraday. The electrotypes, electro-plated ware, and all sorts of artistic reproductions, seem fully to repay the wearisome investigations in the field of electro-chemistry.

But, in passing to and fro through the Exhibition, we have noticed many appliances which owe their utility to some relation between electricity and magnetism, and Oersted's early experiments with the galvanic battery, and his consequent discovery of a direct relation between a current of electricity and a magnet, can no longer be kept in the background. We here come upon another epoch-making experiment.

It was in the course of preparation for a lecture on "Electricity, Galvanism and Magnetism," in the spring of 1820, that Oersted, as he informs us, first tried the celebrated experiment of the effect of a current of electricity on the magnetic needle. It cannot be said that the discovery was altogether unsuggested by the previous

course of science. Franklin had magnetized needles by the passage of the electric spark, and Oersted himself had remarked the uneasy movement of the magnetic needle during a thunder-storm. It was then the next step to imagine the influence of the electric-current on the needle. Oersted not only exhibited the action of the current on the movable magnetic-needle, and conversely by freely suspending a little battery caused it to move by means of a magnet as though itself a magnet, but he brought out clearly the relation of direction of the current to the deflection of the needle. His little pamphlet on the subject, written in the Latin language, and hence at once accessible to all the learned of other countries produced a profound sensation in scientific circles. Eagerly were the experiments repeated and with astonishing rapidity were new discoveries added. In Germany, Seebeck, Erman, Poggendorf and Schweigger took up the subject; and the very galvanoscope then made by Schweigger and Poggendorf by coiling the wire a number of times about the movable magnet so as to multiply the Oersted effect, is our current detector to-day.

It was, however, in France that the news of this discovery was to be crowned by developments of even greater moment than the original experiments of Oersted. Arago brought the news to Paris and, assisted by his friend Gay Lussac, showed that the electric current not only deflected a needle, but magnetized a steel-rod when it was passed through a spiral wound round the rod. They also showed that a wire included in the galvanic circuit actually played the part of a magnet in attracting iron-filings. You remember how similarly the attendants of some of the heavy-current dynamos at the Exhibition amused us all by showing the power of a simple copper-wire to attract nails, files and such like. That, we suppose, was but a playful recognition on the part of the dynamo of its high-born blood.

To André Marie Ampère, however, belongs the glory, not merely of making a few novel experiments but of so theorizing upon the experiments made, and of so inventing new experiments according to theory, and as groundwork for the development of theory that he was enabled to put in place the very corner-stone of the science of electro-dynamics.

And just here we must be permitted to say that there could be no better commentary on the powers of mathematical training in

determining the best course of progress, than to institute a comparison between the articles of Oersted and of Ampère, as they stand recorded in two successive volumes of the *Annales de Chimie et Physique*, of the year 1820. But for the lucid conceptions of the French mathematician, we might still be speaking of the "electrical conflict" of Oersted. To state a few of Ampère's achievements in electricity: He introduced the convention, which has become permanent, of regarding the direction of the current to be that of the positive electrification. He stated so simple a mnemonic for predicting in what direction the needle will be deflected by a current; that the current always "enters the heels" of the practical electrician, and "flows out at his head," when he "looks upon a needle whose north end is deflected to the left." He found that currents acted either attractively or repulsively on currents, according as those were in the same or in opposite directions. But the most important step taken by him was in introducing an electrical conception of magnetism. Since the needle directed itself at right angles to the current, currents flowing from East to West round the earth must produce its magnetism, while artificial magnets are also to be conceived as formed of molecular currents. The whole question then resolved itself into the simple elements of the action of one current on another. The problem was now one of mathematics and mechanics, and he resolved it with abundant success.

As we leave this eminent contributor to the realities of our Exhibition, we cannot omit the beautiful eulogy Clerk Maxwell wrote, when he himself recast the mathematics of the subject: "The experimental investigations by which Ampère established the laws of the mechanical action between electrical currents, is one of the most brilliant in science. The whole, theory and experiment, seems as if it had leaped full-grown and full-armed from the brain of the 'Newton of electricity.' It is perfect in form and unassailable in accuracy, and it is summed up in a formula from which all the phenomena may be deduced, and which must always remain the cardinal formula of electro-dynamics."

We pass now to the next great step that had to be taken before current electricity would become the facile, intelligent servant of the world. This time, also, it is the able mathematician who, in the person of George Simon Ohm, first discloses the won-

derfully simple relations existing between the conductivity of a circuit and the electricity passing. There is no practical electrician, however ignorant of the fundamental demonstrations, or of the repeated experimental and theoretical verifications, that does not pin implicit faith to Ohm's law. Electro-motive force = current $\times$ resistance: is the magical rune now applied in a thousand mystic transformations common to the art and practice of electricity. If space permitted, the line of thought of Ohm's celebrated memoir would be an interesting topic; but we must at least remark that, taking into account the changes in our electrical nomenclature, the very statements of that memoir have now become the familiar conceptions of all who comprehend what is meant by the term "electrical current." Through Ohm, the practice of electricity is also probably a great debtor to no less a mathematician than Fourier; for Ohm himself states how the conceptions Fourier had used in his great work on the theory of heat, were by him transferred to electricity. And we mention this indebtedness in order to be able to hint at the vast obligations due by electrical progress to the prior cultivation of mathematical analysis in other fields. In connection with such an application as that made by Ohm, Fourier's own words seem like a revelation. "Mathematical analysis," says he, "seems to be a faculty of the human mind, destined to supplant the shortness of life and the imperfection of the senses; and what is still more remarkable, it follows the same course in the study of all phenomena; it interprets them by the same language, as if to attest the unity and simplicity of the plan of the universe, and to make still more evident that unchangeable order which presides over all natural causes."

We are now in possession of all the essential elements that go to make up the electro-magnetic telegraph: the voltaic battery, the magnetic action of the current, the laws of that action, and finally the law of Ohm. A new interest in all the variety of telegraphic and signalling appliances displayed at our Exhibition, dawns upon us when thus regarded as the direct and necessary product of researches such as these in the field of pure science. Yet a tithe of the important researches bearing on a line of practice such as that of telegraphy, could not be instanced. Enough has been cited to conclusively show, to what great element in

human progress, an exhibition of these practical results is chiefly debtor. But if it is still doubted whether these scientists ever know what they are doing, and what for, they are doing it, we must remind you how it was in the very highest realms of pure research that the first suggestion of the magnetic telegraph was made, and also the first actual telegraph line constructed and used. For it was within three months after the knowledge of Oersted's experiment, that Ampère had actually proposed the first plan for a telegraphic communication by means of electro-magnetism. And it was between the Astronomical Observatory and the Physical Laboratory at Göttingen that the eminent scientists, Gauss and Weber operated the first practical telegraph line.

The dynamo-electric machines displayed in such variety, and destined to several uses of profoundest interest to us all, will ever remain the prominent features of the Exhibition; as in memory, we pass through the fascinating scene. Those dynamos always excited our respect. Their very crudeness did not even detract from this feeling. There was about them a certain masculinity of character that impressed itself on everyone, and gave a tone of work-a-day earnestness to the entire Exhibition. This earnestness of spirit was real and gave promise of a vigor of progress for the future, that should equal, and doubtless excel, the historical development of the steam-engine.

While the variety of type pleased the mechanical fancy, it did not daze the scientific analysis. However crude or however typical of what the future dynamo may be expected to be, each machine was readily analyzed into its essential elements and the action of these referred to the original principles of science.

There are two great events in science that made the dynamo-electrical machine possible; one is that of the discovery of magneto-electric induction by Faraday, in 1831; the other that of the establishment of the great laws of the correlation of forces and the conservation of energy, during the fourth and fifth decades of this century by a goodly array of mathematical and experimental genius. Without the well-known researches of Faraday on magneto-electric induction and the consequent development of the magneto-electric machine from the early Dal Negro and Pixii types up to the Alliance and Pacinnotti, there could not have been a suitable preparation for the improvements of a Siemens or a

Gramme. And as an ever-present reminder of the value and eventual use to mankind of such researches, there should be stamped upon every dynamo the name of Michael Faraday.

Again, it is quite remarkable that the title of Werner Siemens' article, in which he in 1861 announced the dynamo-electrical or reaction principle, should have read: "Concerning the Conversion of Mechanical Energy into Electrical Current, without the Use of Permanent Magnets." It is but an evidence that the other great discovery in science referred to, had borne one of its legitimate fruits. Everyone is now familiar with the history of the discovery, proof and application of the laws of energy by Mayer, Joule, Thomson, Helmholtz, Clausius, and others; and everyone also with the kind of science these names imply.

We can therefore pass on to another definite instance of the fruits of the law of conservation of energy that should be mentioned in this connection. We have already spoken of Ohm's law, which is, of course, also here applicable in the dynamo; but we purposely, hitherto, omitted to mention the second law of electrical currents, because of its peculiarly useful relations to problems concerning dynamo currents. According to this law heat is generated or work performed in any given circuit in the following relation: quantity of heat = square of current × resistance × time. There is scarcely a practical calculation concerning the performance of the dynamo into which this little formula does not enter. It is the key that is constantly in the hands of the practitioner and that easily unlocks the dynamical riddle of the new engine. This time it is the experimental researches of Joule and Lenz, which first proved the relation, and it is the mathematical skill of Clausius that finally expressed the law as a deduction from principles already known.

It would scarcely add to the force of our main argument if we should go further and show how the whole dynamo-electric-engine has been subjected to a series of scientific tests, and of theoretical discussions which are destined to make a special kind of engineering. Enough that we can now, at least with partial insight, derive the scientific origin of the dynamo from the old-time rubbing of a piece of amber.

We must also omit discussion of the deep obligation due by our Exhibition to pure research in developing the very steam-

engine necessary to the generation of the new form of energy. To mention the bearing of Regnault's researches and the influence of the mechanical theory of heat, would lead us far away from the electrical side, and is here unnecessary.

We will, however, as we glance at the work to which the current generated in the dynamo is put, remark that it was in Davy's laboratory that the electric arc was first brought out in all its glory. We now see *hundreds* of arc lamps above and around us. Turning to the soft and beautiful light of the incandescent lamps, we see in imagination the spiral of wire that, under the electric discharge, became glowing in Kinnersley's old air-thermometer. If we see the dynamo-current at work in the chemist's hands, we have again to recall Davy's experiments and Faraday's exposition of the laws of electrolysis. If we watch the electric-motors, as they drive all sorts of machinery, we are borne back in imagination to the year 1835, and with the great physicist, Jacobi, of St. Petersburg, we go sailing up and down the Neva in a boat propelled by a magneto-electric-engine, while we learn from him some of the laws underlying the wonderful result.

It is the ocean cable, only present in our Exhibition by proxy, that must next serve as the text for a brief reference to the beneficent influence of mathematical theory in general and of the theory of the potential in particular, in bringing about the great achievements. The practical electrician we have ofttimes met in our wanderings through the Exhibition, has spoken of the electrical "potential" as though that were something to put one's ignorance to the blush. But we have sometimes wondered whether he imagined that the word stood primarily in electricity for a purely mathematical conception, which he now unconsciously regards as a physical fact. Moreover, in the occasional references to the indebtedness of practical electricity to mathematical investigation, we have not been able to give even a partial idea of the theories developed, or of their bearing on practice. The only way in which we can pretend further to supply this omission, is to state, in a few sentences, the influence of a single mathematical conception on the progress of the computation of the electrical forces. Laplace, in treating the attractive forces of gravitation, had used a function essentially proportional to the attractive masses and the simple inverse distance. This function, V, has since become

famous for its power in dealing with all problems in which the forces act according to the inverse square of the distance. Green and Gauss first applied it to electrical problems, the latter to a general investigation comprehending gravitation, magnetism and electricity, and subsequently Sir Wm. Thomson and others used it as the very key to the solution of the most difficult problems. Now, to use the cable as an illustration of the practical bearing of researches apparently so far removed from actualities, we find that Sir Wm. Thomson, using the conception of the potential, already in 1855 derived the little formula which expresses the electrostatic capacity of a cable, considered as an immense leyden jar. We stand amazed when, after the breaking of a cable, we see a vessel sent to mid-ocean, there to put down grappling-irons through miles of water and successfully recover and splice the artery of commerce. But we should not forget the little formula, whose use could point to the very spot where the break must have occurred; and we should not fail to remember the formula's out-of-the-way origin.

As we take our parting glance of the fascinating and successful exhibition, we may sum up all in the statement that electricity is now subject to accurate measurement. The magnetometers, electrometers and galvanometers and the multiplicity of meters that measure every conditions of electrical action, stand as the crowning result of theoretical and experimental electricity. If we ask, why the instruments are of such and such forms, we are referred to the mathematics; if we inquire how they are used, we learn also the necessity of acquiring the art and practice of experimentation. If we inquire upon what general method the measurements are made, we are sent all the way back to the great astronomer Gauss, to learn of him the absolute system of expressing forces, and if we ask for the unit of measure, the yard-stick of the practical electrician, the so-called ohm, we have to intercede with the long line of eminent physicists, beginning with Wilhelm Weber and ending with Rayleigh and Rowland for a copy of their standards.

In every element of the Exhibition we detect the most undoubted relations to pure research; and when we run over the scene even thus cursorily, we behold pure research the presiding

genius, on whose behests depend the successful activity of every department of electrical practice here represented.

The lessons to be drawn from this review are evident. Research in America should be raised to a higher plane and such methods adopted to bring about the desired result as may have the sanction of past success. The reason why there are not more American names associated with the progress of physical research (and there are many more in this department than we have had occasion to mention), does not lie in the lack of interest, or the lack of power in the American student. Apart from the materialistic spirit that we all imbibe, there is the lack of the appliances and particularly of the unrestricted devotion that such work demands.

Speaking of appliances it is at least in the separation from first-class scientific libraries that the American student suffers untold inconvenience. European students in physics would be amazed to learn that in an American city of nearly one million of inhabitants, there could not be found a complete set of, say, Poggendorf's Annalen or Crelle's Journal, or an instance of other volumes which it were occasionally desirable to refer to, in order that experimentation might start in at the right point and lead to the right end. Especially, however, do we wish to insist on the fact that sufficient opportunity is not afforded for that jealous, single-minded attention which science requires. It is not that large endowments are not given to erect fine buildings for laboratories or to provide fine instruments. But it is that there are but few foundations which put the man back of the instruments and allow him to devote himself with undisturbed purpose to the work of his laboratory. If you will recall the influence of but one institution where a foundation is provided which places an unhampered man in the laboratory, you will appreciate the justice of these remarks. The Royal Institution of London was founded, we are told, to promote, among other things, scientific research. To do this it founded a professorship, which gave the incumbent free scope to follow out researches of the purest type. You know what has been done for electrical science by its professors, Davy and Faraday. They discovered the decomposition of the fixed alkalies, the laws of electro-chemical decomposition, the fact of magneto-electric induction and the two-fold magnetism of matter, together

with a whole body of general information on electrical subjects. You know then how deep a debtor our Electrical Exhibition was to this single foundation for the promotion of research. It need only be said that the prospect is clearly open of doing not only important service to science, but some day to humanity at large, by diverting some of the American wealth to such noble foundations. May we not hope that our public-spirited citizens will thus endow our own INSTITUTE, an institution in many respects similar to the one just mentioned. Such a happy result would certainly show that America was not altogether oblivious of its lasting obligation to the contributions already made toward its material and social progress, by the eminent cultivators of pure research.

ON THE FRICTION OF NON-CONDENSING ENGINES.

BY R. H. THURSTON, ITHACA, N. Y.

[*A Paper read at the Meeting of the American Society of Mechanical Engineers, New York, November 30, 1886.*]

The assumption of the distinguished engineer, De Pambour, that the wasteful resistance of a steam-engine consists of a constant quantity, the friction of the unloaded engine, increased by some increasing function of the added load, has been accepted as correct by probably all recognized authorities since his time. Calling R_0 the resistance of the engine running free and under no other load than its own friction, and calling R_1 the resistance coming upon it as a useful factor of its work, and making f the coefficient measuring the proportion of increased friction due to the load, the total resistance to be overcome by the engine piston is thus

$$R = (1 + f)\, R_1 + R_0 \qquad (1)$$

So far as the writer has observed it has never been questioned whether the quantity f is constant or variable, and no recent attempts have been made to ascertain its value by experiment.

It has long been the intention of the writer to settle this question, which had for years existed in his own mind, and the opportunity has recently been offered to do so, at least as that question affects the modern forms of non-condensing high-speed engines now so generally in use, especially for electric lighting purposes.

The first investigation was made at the suggestion of the writer and under his general direction, in the winter of 1883–84, upon a "straight-line engine," exhibited that year, at the Annual Exhibition of the American Institute, by the Straight-Line Engine Company, of Syracuse, N. Y., and built by them from the designs of Professor John E. Sweet, the inventor of its special features. The work was done with equal care and skill by Messrs. Mitchell and Aldrich, graduates of Stevens Institute of Technology, of the class of 1884. The results were sufficiently exact and satisfactory in every respect to have been made the basis of the conclusions here to be

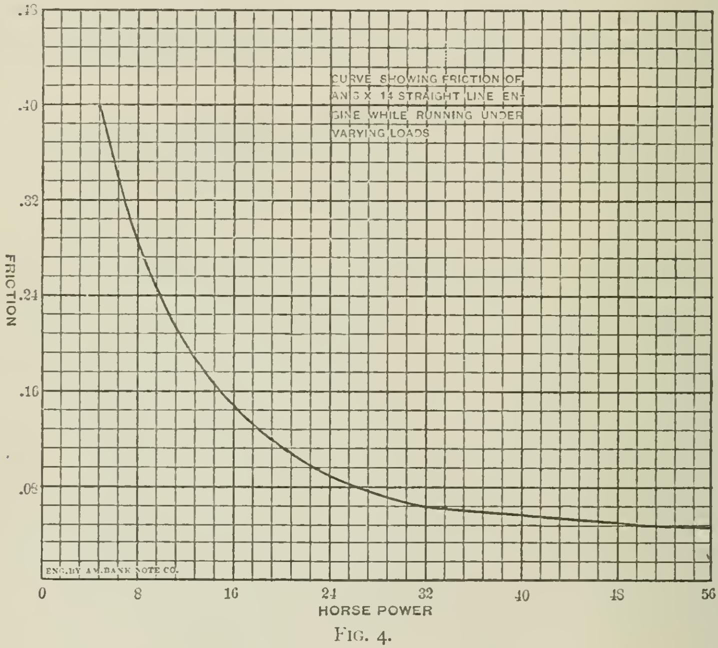


FIG. 4.

stated; but it seemed to the writer desirable that they should be checked by similar work upon another engine, if possible of a different make, before attempting to state definite conclusions of any kind. The opportunity to secure such a repetition of the investigation was offered, during the past winter, at Cornell University, using a straight-line engine, which could be fitted with a brake, and conveniently submitted to test. The engine is of the same make as the first described, but of a different size, and the results of the two sets of experiments are considered to accord so thoroughly as

to justify publication. The following are the data and results of these two sets of determinations:

The first of these two engines was built from designs brought out in the year 1880, of which illustrations may be seen in the *Electrician* of December, 1883. As is well known, the engine derives its name from the fact that, in its design, the attempt has been made to take all stresses through straight members, the frame thus being made to consist of two straight compression and thrust members, connecting the cylinder-heads directly with the main pillow-blocks, and giving a characteristic appearance to

METHOD OF ATTACHING THE INDICATORS.

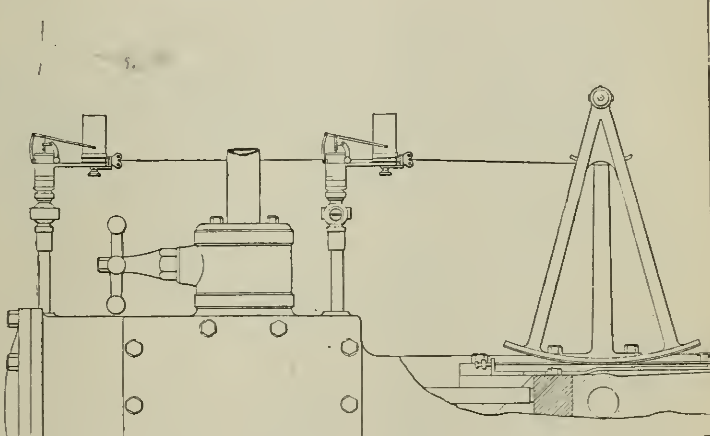


FIG. 1.

the whole machine. The valve-gear is of the "positive" type, the expansion made variable by the introduction of a governor on the main-shaft actuating the eccentric, in the manner familiar to all who have seen the more common forms of high-speed engines. In the design of this governor, as throughout the whole engine, special care has been taken to provide against the impeding action of friction, the machine being intended to be as nearly frictionless as possible. The engine rests upon three points of support, and thus is not liable to be thrown out of line by any inequalities of foundation or bolting. When tested, the engine to

be experimented with was simply set on blocking, and had no foundation; but so well was it balanced, and so perfectly was its alignment maintained, that it ran with absolute smoothness, and as steadily as if it had been given the heaviest foundation possible.

For the purposes of test, it was fitted with a pair of carefully standardized indicators and a Prony brake. Cards were taken simultaneously from both ends of the cylinder, and readings from the brake were at the same instant obtained. A comparison of the power indicated by the diagrams, with that shown by the brake

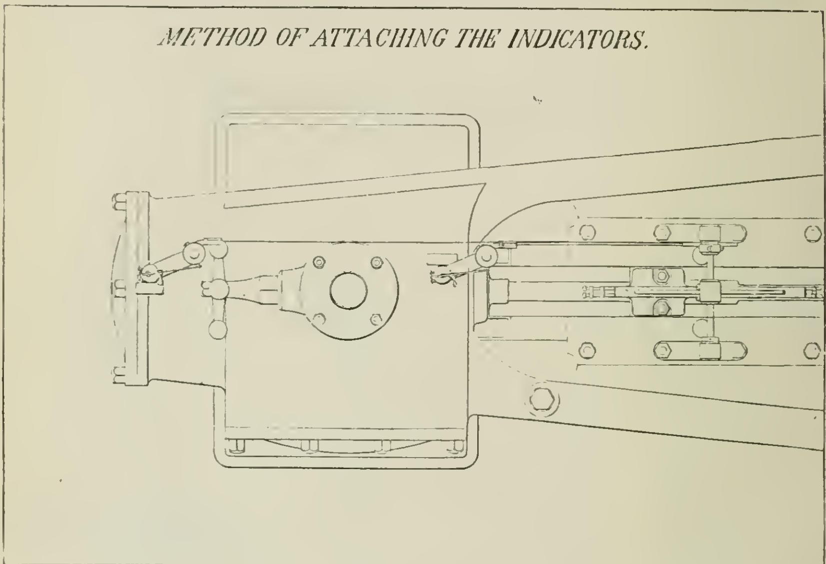


FIG. 2.

gave a difference which measured the friction of the engine. During the trial, the engine, when working at its rated power, consumed, according to the indications of the diagrams, 28·2 pounds of steam per horse-power per hour, or probably between thirty-five and thirty-eight pounds, allowing for the loss by cylinder condensation not accounted for on the indicator card, a very excellent performance for an engine of but thirty-five horse-power. The action of the governor was extraordinarily perfect. The engine was adjusted to make 230 revolutions per minute under ninety pounds steam-pressure. The observers reported that it made the same number of turns whether loaded or unloaded, an evident

impossibility with a governor of this class, in which only approximate isochronism can be attained. The writer, to settle the question, counted the revolutions, minute by minute, with a hand-speed counter, and made it 230 revolutions with the whole rated load on the engine (thirty-five to forty horse-power), and 231 when entirely unloaded, the brake-strap being loosened until it could be shaken about on the pulley, by the hand, with perfect ease. This was repeated until no question could longer exist in regard to the matter. The variation with variable steam-pressure was greater.

The following are the data obtained from the brake and indicator readings:

Number of Card.	Revolutions.	Steam-Pressure.	Brake H.-P.	Indicator H.-P.	Diff.	Friction per Cent.
1	232	50	4·06	7·41	3·35	45·
2	229	65	4·98	7·58	2·60	34·
3	230	63	6·00	10·00	4·00	40·
4	230	69	7·00	10·27	3·29	32·
5	230	73	8·10	11·75	3·65	32·
6	230	77	9·00	12·70	3·70	29·
7	230	75	10·00	14·02	4·02	28·
8	230	80	11·00	14·78	5·78	25·5
9	230	80	12·00	15·17	3·17	21·
10	230	85	13·00	15·96	2·96	18·5
11	230	75	14·00	16·86	2·86	17·
12	230	70	15·00	17·80	2·80	15·75
13	231	72	20·10	22·07	2·06	9·
14	230	75	25·00	28·31	3·36	11·75
15	229	60	29·55	33·04	3·16	9·5
16	229	58	34·86	37·20	2·34	6·3
17	229	70	39·85	43·04	3·19	7·4
18	230	85	45·00	47·79	2·75	5·8
19	230	90	50·00	52·60	2·60	4·9
20	230	85	55·00	57·54	2·54	4·4

This engine was 8 inches in diameter of cylinder, 14 inches stroke of piston, having a rod 44 inches long between centres, a balanced-valve with stroke of 2 to 4 inches, according to position of governor and eccentric, a fly-wheel 50 inches in diameter, weighing 2,300 pounds, the stem and exhaust-pipes having diameters of 2½ and 4 inches, respectively, and the whole machine weighing two and one-half tons. The space occupied by the engine was 9 feet 4 inches in length, by 4 feet 8 inches in width, and 3 feet 10 inches in height.

Examining the above table of powers, it is seen that the difference between indicated and dynamometric power, *i. e.*, the friction of the engine, varies somewhat with varying steam-pressures and varying total power; but in such manner as to indicate the controlling cause to be irregular in action, and possibly to some extent due to errors of observation and to accident. The maximum

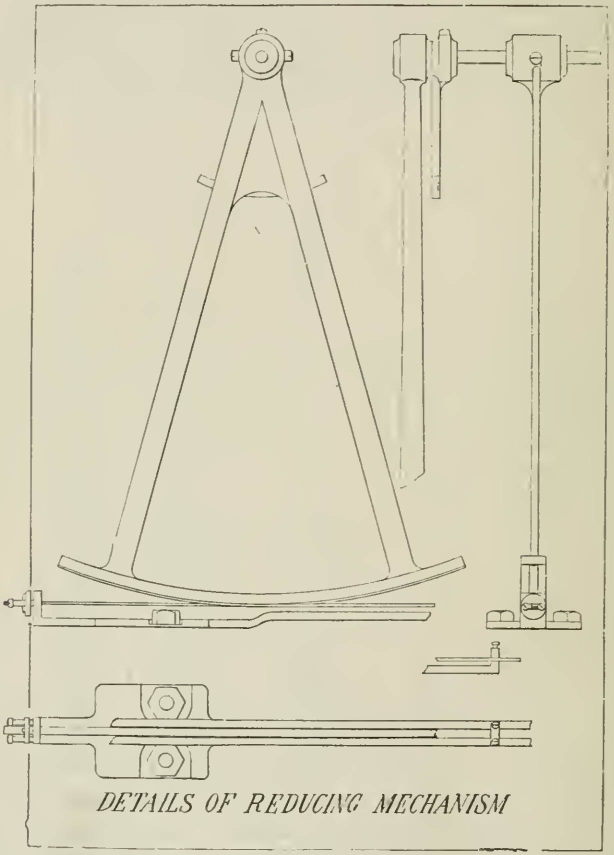


FIG. 3.

is four horse-power, the minimum about two horse-power. The usual difference is about three and the variations are irregularly distributed throughout the whole range of experiments. It is evident at a glance that the law of De Pambour does not hold, and that it is much nearer correct to say that the friction of engine is constant as otherwise. The column of friction, as given in per-

centages of the total power, exhibits the same fact. There is continual, though somewhat irregular, reduction of the percentage of friction, throughout the range from the lowest to the highest power, and very nearly inversely as the power exerted. This is best shown by the curve given in the accompanying plate, *Fig. 4*, in which a smooth line has been drawn to represent as nearly as possible the mean of all observations. It is evidently more nearly correct to assert that the friction of a non-condensing engine of this class is constant, and independent of the total power developed, than to accept the rule of De Pambour. The power for which the engine is proportioned is thirty-five to forty horse-power. At this power, the friction of engine is but about six per cent. of the total, or less than one-half that assumed by De Pambour, and accepted as correct by Rankine, for engines generally, and presumably for locomotives especially. The result is exceedingly gratifying, and the friction seems to the writer extraordinarily low for so small an engine.

The repetition of the experiment upon an engine of another make, having a cylinder 9 inches in diameter and a stroke of piston of 12 inches, which would naturally give a somewhat increased percentage of friction, in consequence of the proportionally smaller stroke, at twenty, thirty, fifty and sixty-five horse-power, by brake, and running free, revolutions 300 per minute—a speed which may also have caused some increase in frictional resistance, not only in rubbing parts, but by increasing back pressure—gave a friction of engine measuring from 2·66 horse-power unloaded, to four horse-power at twenty to thirty horse-power, 4·8 horse-power at fifty, and 5·3 at sixty-five horse-power, the total friction increasing perceptibly, as assumed by De Pambour, but decreasing in percentage of load, from 16 to 7·5, between twenty and sixty-five horse-power. It is very nearly constant throughout the whole range of power that the engine would be worked through under ordinary circumstances, and may be so taken without serious error; while the adoption of the Pambour formula would give a value of f so small that its use would not be attended, ordinarily, with sufficient increased exactness to compensate the additional trouble involved in its application. At their rated powers the two engines thus exhibit efficiencies of mechanism of about ninety-four and ninety per cent. respectively.

The second series of experiments were made by Messrs. W. A. Day and W. H. Riley, at Cornell University, during the latter part of last college year, confirming the deductions already given, while some very interesting and original modifications were made in the details of method and trial. The engine taken for test was a machine recently built, and sent to the Cornell University, for purposes of experimental investigation in electrical measurement and other work of the college. It is an engine 7 inches in diameter of cylinder and 12 inches stroke, or, more exactly, 6½ inches in diameter, the cylinder having been bored slightly under size. The general plan of the engine is similar to the first of those already described, and, like that, is carefully designed with a view to reducing friction to a minimum and giving a regulation of maximum efficiency. The brake was precisely like that used in the first described experiments, and was built for the engine constructed in the college work-shops, under the direction of the inventor, and exhibited at the Centennial Exhibition, in 1876. It was constructed by the Straight-Line Engine Company, and adapted, with very little alteration, to the new engine. The indicators were carefully standardized and put in good order in every respect, by the makers, for the purposes of these investigations. The reducing mechanism used in connecting the indicator-barrel to the cross-head of the engine was designed and built by the observers, and fitted with a very firm connecting arrangement, and with an ingenious detaching device (*Figs. 1, 2, 3*). A sector was constructed which was pivoted above the cross-head and hung in the vertical plane above the latter, the engine being horizontal. The arc of the sector carried a pair of steel ribbons, one attached to each end, each carried around the arc and secured, at its opposite end, to the end of a bar fastened on the cross-head, in such manner that, the two ends of the ribbons at the cross-head bar being well secured and tightly drawn up by means of screws placed conveniently for the purpose, all back-lash was prevented, and an absolutely exact synchronism of movement of indicator-line and cross-head was obtained. The engine was driven at 285 revolutions per minute, and it was, therefore, very important that this rigidity of connection should be secured. A smaller sector at the upper part of the larger one was the carrier of the cord, and the combination was thus a perfect means of reproducing the motion of the engine on

the smaller scale required in working the paper-barrel of the indicator. The "cord" was piano-wire, a material much less liable to cause difficulty by stretching than any other that was available. Its free part was kept taut by a "spiral" (helical) spring, attached beyond the point of connection with the paper-cylinder.

In the first of these experiments, as already described, Thompson indicators were used; in those about to be considered Crosby instruments. It was hoped that the new Tabor indicator could be used also, but none were received in time. The instruments

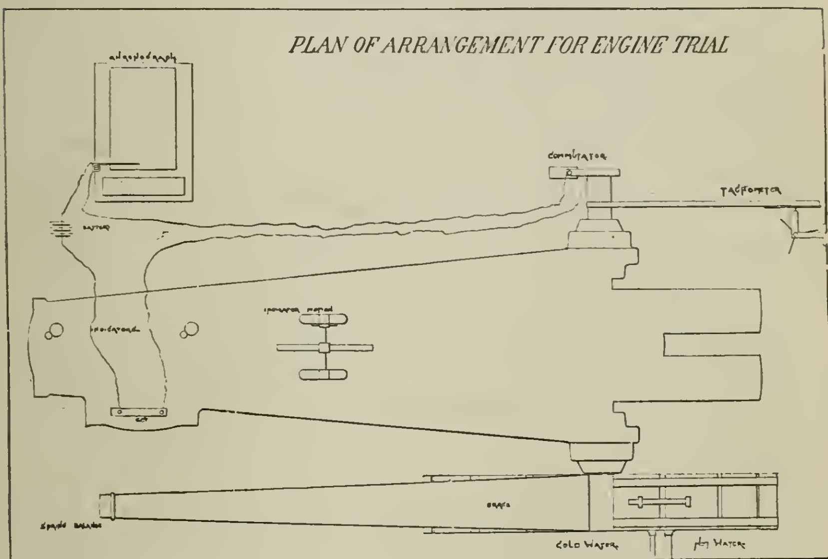


FIG. 5.

used worked perfectly, and gave no trouble from beginning to end. The speed indicators were of several kinds. Hand instruments of two or three kinds were used to check the records of the automatic instruments. A "tachometer" was attached and belted to the engine-shaft, and afforded a very convenient means of watching the momentary fluctuations due to variations of load, of steam-pressure, and to accidental disturbances. A chronograph was also attached, connected with the standard clock in the physical laboratory, to beat seconds. A commutator was placed on the engine-shaft, making contact at each revolution, and a key near the engine, for the purpose of breaking contact. A Brown mercury

speed-indicator served excellently well for a constant speed-indicator. It exhibited instantly any variation of speed from the normal. The chronograph was set in operation when the indicator-cards were taken, and thus gave the exact speed of the engine at that instant. Great care was taken to keep the instruments, and the

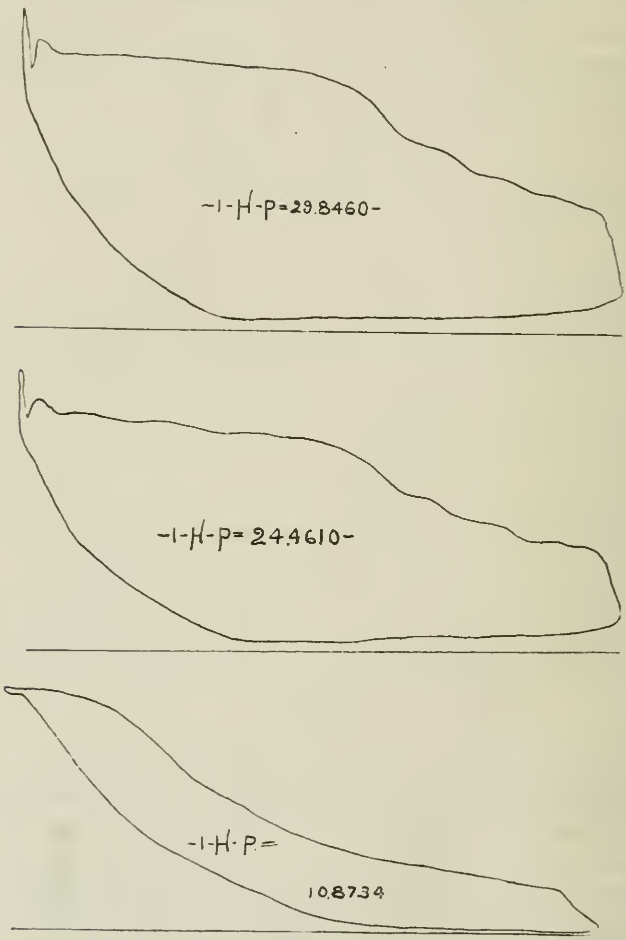


FIG. 6.

engine as well, in good order and well lubricated throughout the series of experiments. Some stiffness of the governor, however, the cause of which was not discovered until after the work had been completed, caused it to work less perfectly than in the engine first

used, and the speed varied more than in that series of determinations. When the governor was in its most perfect adjustment, the engine was capable of holding the standard speed within a fraction of one revolution throughout a wide range of work, and nearly down to the lowest power that such an engine is at all likely ever to be called upon to supply.

The mean effective pressure required to drive the engine itself, loaded and unloaded, throughout the whole range of the trials here made, was 4·55 pounds per inch of piston, and was nearly constant, as in the first investigation. The steam-pressure usually ranged between sixty-five and seventy-five pounds per square inch at the steam-chest; but, when it was desired to secure a more easily worked-up card, the pressure was dropped to twenty pounds. A series of special experiments made to determine the question whether the friction of engine is variable with boiler-pressure, although not in all respects satisfactory, indicated a slight increase in engine friction as steam-pressures rose. The conclusion already arrived at by the writer, as deduced from the work previously done, that the engine-friction, in this class of steam-engine is constant, or sensibly so, under all loads is thus here again confirmed. The following are the data obtained, arranged as before, to exhibit the relation of the indicated to the dynamometric powers:

1. No. of Card.	2. Rev. per Minute.	3. St.-Press.	4. Brake-Power. H.-P.	5. Ind. H.-P. per Card.	6. Diff. Frict. H.-P.	7. Mean F. Press.	8. Frict. per cent.
1	282	19	0	2·26	2·26	3·70	100
2	288	65	4·87	8·43	3·56	5·56	42
3	286	66	7·61	10·95	3·33	5·25	30
4	284	65	10·30	12·93	2·89	4·13	20
5	285	71	13·10	15·99	2·61	4·25	18
6	284	76	15·80	18·79	2·99	4·71	16
7	284	74	18·55	20·73	2·65	4·18	12
8	280	67	21·00	23·73	2·73	4·37	11
9	279	65	23·61	25·95	2·33	3·73	9
10	280	75	26·39	29 95	2·36	5·38	11
11	280	72	29·03	32·22	3·19	5·15	10

The first glance at column 6 or at column 7 of the above table, in which the horse-power absorbed by the friction of the engine,

and the mean effective pressure corresponding to that power are presented, shows that, as already concluded, the resistance of this class of engine at constant speed, is practically constant at all loads and that the differences and irregularities observed are due to accidental causes. The variation of speed recorded here is in some cases due to differences of steam-pressure, partly purposely produced, and partly coming of the fact that it was necessary to take steam as it could be obtained, and was impracticable to secure steady pressure, and in other instances was due to the fact, afterward discovered, that the governor had been adjusted in such manner as to be slightly cramped, and thus deprived of its wonderful sensitiveness and accuracy, as exhibited before this defect had been introduced, and after it had been remedied. Chronograph records, made later by Professor Anthony, exhibit the most extraordinary smoothness.

No. of Cards.	Rev.	St.-Press.	I. H.-P.	Mean Press.	Mean F. Press.	Per cent. Frict.	
1	250	25	6·01	10·84	1·95	18	Ten pounds on the brake.
2	271	39	6·52	10·85	2·71	27	
3	285	42	7·17	11·35	3·63	32	
4	280	46	7·08	11·60	3·59	31	
5	271	58	6·81	11·28	3·16	28	
6	289	63	7·85	12·25	4·65	38	
7	286	68	7·77	12·25	4·90	40	
8	283	77	7·88	12·47	3·74	38	
9	296	82	7·87	12·00	4·68	39	
10	275	71	2·10	3·46	3·46	100	
11	279	66½	1·995	3·22	3·22	100	No load on the brakes.
12	277	44	1·708	2·78	2·78	100	
13	275	35	1·71	2·80	2·80	100	
14	275	30	1·613	2·64	2·64	100	
15	272	25	1·876	3·11	3·11	100	
16	270	19	1·724	2·88	2·88	100	
17	270	15	1·712	2·86	2·86	100	

These variations of speed served the useful purpose of calling attention to the fact that the engine-friction varied, at constant load and speed, with variation of steam-pressure, and to a very noticeable amount, within the usual range of pressures met with in practice. It is seen that, in rising from nineteen to seventy-six

pounds steam-pressure, the pressure demanded to give the engine its normal speed unloaded ranged from below four to above five pounds per square inch of area of piston, the pressure required in the cylinder rising, on the whole, though irregularly, as steam-pressure rose. In order to determine whether this, which might prove to be a hitherto unobserved law, were true, the foregoing data were obtained by a series of experiments made for the purpose of settling this new question.

In the first set of experiments, here numbered 1 to 9, inclusive, the weight on the brake-arm was kept constant at ten pounds; in the remaining experiments, all weight was removed. In both sets, the same general effect is seen. As the steam-pressure rises, the speed being the same and the resistance the same, the friction of the engine increases; from two pounds, at twenty-five pounds pressure in the steam-chest, to nearly five pounds per square inch of piston at the maximum, eighty-two pounds steam in the valve-chest. As the steam-pressure fell from this point to fifteen pounds in experiments 9 to 17, the load being thrown off entirely and the speed being nearly constant, the mean pressure measuring the friction of engine falls again below three pounds per square inch of piston. The difference is considerably less in the last series than in the first, which apparent discrepancy is accounted for by the fact that the variation of steam-pressure in the first series was accompanied by a greater change of speed of engine than in the second. The resistance is seen to increase slowly, therefore, with increase in speed of rotation. The effect of change of pressure is, in these cases, more marked than that of alteration of velocity of the engine.

The accompanying plates illustrate the apparatus and exhibit the facts revealed by the investigations which have now been described better than can the text. *Fig. 1* shows the method of attaching the indicators, with an elevation of the engine-cylinder and section at the cross-head; *Fig. 2* exhibits the same arrangement in plan; *Fig. 3* gives an enlarged view of the reducing mechanism and attachment to the cross-head; *Fig. 5* is an outline plan of engine and surroundings, exhibiting the location of instruments; and *Figs. 6* and *7* represent characteristic diagrams obtained by means of the indicator, showing the variations of steam distribution with variations of load on the brake. All these

illustrations refer to the work of later date. *Figs. 8* and *9* are given to exhibit the method of variation of mean friction-pressures

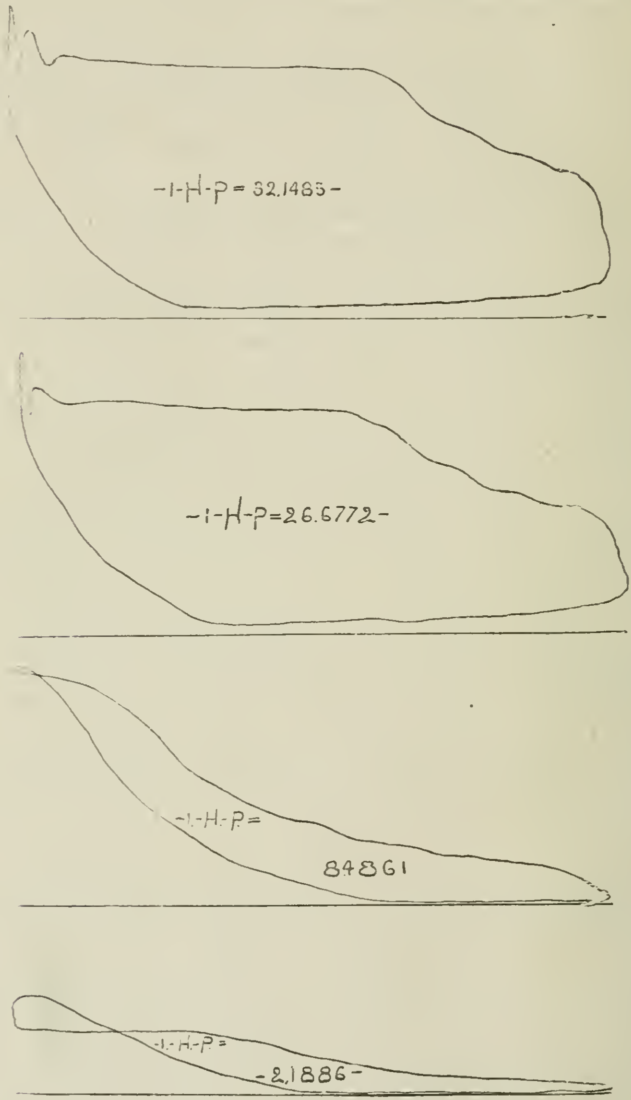


FIG. 7.

with variation of load, the variation of the percentage of friction resistance as a fraction of total resistance with varying loads, for

the last investigation; and, for comparison, the same ratios, as obtained in the work done at the American Institute Exhibition,

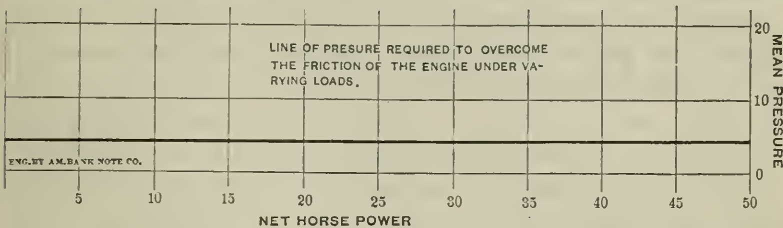


Fig. 8.

are given in *Fig. 4*. These last curves are seen to be approximately hyperbolic; while the first given is a straight line. The

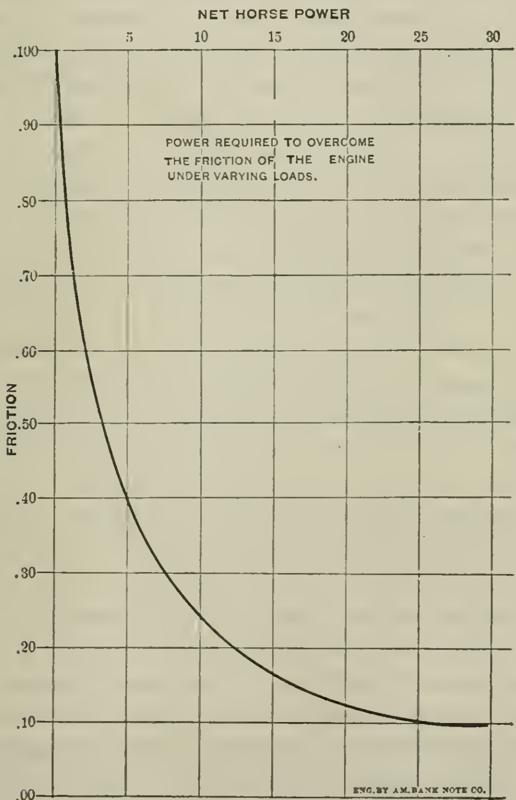


Fig. 9.

originals of these curves were carefully plotted by Messrs. Day and Riley, from the records of original observations, and beauti-

fully represent the law which it was the object of these investigations to reveal and establish.

After a survey of this work, it may be asked, How does it happen that rise in steam-pressure produces evident increase of the frictional resistance of the engine? It was long ago shown by the writer, and is now well established by many independent investigations, that, with good lubrication, increase of pressure on a journal gives decreased coefficients of friction, and this would seem to show that the friction of engines in which the resistance caused by friction is mainly due to journals and lubricated surfaces, should become less as pressures increase, the useful load and the speed of engine remaining constant. This query is a very natural one, and is based upon a correct statement of fact, however inconsistent it may seem to be with the results above derived. The cause of the apparent discrepancy is attributable, probably, to the variation produced by the action of the governor in the distribution of steam. It will be seen that the effect of increase of steam-pressure is to cause acceleration of speed of engines, a change essential to produce the action of the governor at all, and that it results in the readjustment of the set of the valve in such manner as to cause the greater proportion of the nearly constant amount of work performed to be done more nearly at the commencement of the stroke, at a point in the orbit of the crank-pin at which the work is mainly lost by friction, and to reduce the proportion of total work done at or near the "half-centre," where it is principally useful. The proportion of useful to lost work is thus varied in such manner as to give a mean final result which is the less favorable as the steam-pressure is higher, and the cut-off shorter, giving a higher ratio of expansion. It is also evident that, if this explanation is correct, the difference here noted will be less as the point of cut-off approaches and passes the half-stroke position of piston and cross-head. Could the valve be set with negative lead for all positions at the point of cut-off, as is considered right by some experienced engineers, the work would be more nearly performed at positions removed from the "dead points," and the variation here described would be thus reduced, while the efficiency of the engine would be increased.

Professor Rankine proposed the formula,

$$R = R_1 (1 - f) \qquad (2)$$

This formula is evidently inadmissable, at least for the class of engine which was made the subject of the experiments which have been here described. Since the friction of engine is, so far as can be here seen, sensibly independent of the magnitude of the load and of the resistance produced by it, the correct formula would seem to be

$$R = R_1 + R_0 \qquad (3)$$

the total resistance met at the piston being the sum of the resistance of the engine itself and that of the load, both being determinable, both being independent, and being governed by entirely different laws.

The conclusions to be drawn from what has preceded are obviously the following:

(1.) The friction of the non-condensing engine of the class here described, is sensibly constant at any given speed at all loads, and is at different speeds entirely independent of the magnitude of the load.

(2.) The friction of engines of the type described is variable with variation of speed of engine, increasing as speed increases, in some ratio as yet undetermined, but probably different with every engine, and, for the same engine, with every change of conditions of operation.

(3.) The friction of engines increases with increase of steam-pressure, in the case of the class here referred to, in a probably similarly variable manner with that observed with alteration of speed, neither method of variation being capable of representation by any convenient algebraic expression.

(4.) The total resistance measured at the piston of the engine is composed of two parts, the one sensibly constant at the working speed, the other variable with external load, and may be, for practical purposes, at least, represented by the expression,

$$R = R_1 - R_0,$$

in which R is the total resistance, as shown on the indicator diagram, R_1 the resistance due to the external load; *e. g.*, as measured by a Prony brake, and R_0 the resistance of the unloaded engine, as shown by a "friction-card" taken with the steam-engine indicator.

It is sufficiently obvious that these conclusions are, at present at least, only certainly applicable to one class of engine. It is

not improbable that the condensing-engine may be subject to quite different laws. It is to be hoped that this question may be settled by direct experiment at an early day. The custom has obtained, hitherto, of allowing a certain pressure per square inch of piston as the equivalent of the friction resistance of the engine in marine practice—this pressure being taken at from two and one-half pounds in the case of engines of moderate size, to one and one-half with the largest engines. It has never yet been ascertained whether, or to what extent, the friction of engine is augmented by the imposition of load. The assumed figure represents from five to ten per cent., usually, of the total indicated power of the engine. Isherwood has taken seven and one-half per cent. of the useful load as the amount of increase of friction of engine due to its action. This estimate is stated to be made on the basis of the data given by General Morin, whose coefficients for friction of lubricated surfaces are now known to be enormously larger than those customarily met with in practice in well lubricated journals of large size working under heavy pressures. In such cases, when the surfaces are in good order, the coefficient is known to fall to below one per cent., instead of being from three to five, as given by Morin, as determined under the different conditions of his experiments. Where the journals are not well lubricated, and especially when they are rough or cut by abrasion, friction may increase enormously and may pass far beyond the figures given by Morin even; but such exceptional conditions cannot be taken into account to establish laws for application in design, or in good practice. For all cases in which the friction varies, as in the examples here above illustrated, the "friction-card" sensibly represents the correct tare, whether the engine be loaded or unloaded.

A word in explanation of the fact here shown, that the increased load thrown upon the shaft, crank-pin and cross-head journals does not noticeably increase the friction of engine, will be considered not out of place here. The friction of engine consists of the resistances due to the motion of the various piston, valve and other rods through stuffing-boxes and in guides, the friction of the piston-rings on the cylinder-surface, the friction of eccentrics, and often other parts which are independent of the magnitude of the load thrown upon the engine by the useful resistance, in addition to the

friction of the journals transmitting the effort of the steam to the exterior resisting work, and of the cross-head guides and other parts indirectly affected by its variation. It thus happens that the resistance due to the friction of the latter may be, and often is, but a small proportion of the whole friction of engine. The total friction of engine, as has been seen, in engines of the class here studied and of the sizes described, amounts to about ten per cent. of the total power developed when fully loaded ; but the coefficient of friction of any one journal, if well lubricated, has been found by the writer, by hundreds of experiments, under such pressures as are usual on the main journals of the steam-engine, to fall below one per cent., and the absorption of work and energy is thus a still lower proportion of the work of the steam in proportion as the speed of rubbing is less than that of the piston. The loss of power along the line of connection is thus exceedingly small. It should never exceed probably two per cent. of the work done, or between ten and twenty per cent. of the total friction. Again, the coefficient of friction, within the usual range of pressures on these journals and the guides, with good lubrication, increases rapidly as pressures fall, and decreases as greatly when the pressures increase with variation of engine-power and load, and this change often occurs so rapidly that the total frictional resistance, on these parts even, varies very slowly with variation of load, while the friction of the other portions of the engine, above mentioned, remains quite constant. The resultant effect is, as shown by the investigation here described, a practically constant friction of engine under all loads, the speed and steam-pressure being constant. Whether this is true of condensing engines is doubtful, and it would be an important extension of this research could similar investigations be made of the friction of other forms, and especially the marine steam-engine and pumping-engines.

New Alloy of Aluminium.—Bourbouze recommends an alloy of aluminium, ten parts; tin, one part; sp. gr, 2·85, as more easily worked and soldered than aluminium. It is also somewhat whiter.—*Comptes Rendus, June 7, 1886.*

Extensions of Raoult's Law.—Raoult finds that his law — that the solution of any organic molecule, not an acid or alcohol, in 100 molecules of liquid lowers the freezing-point about 0°·62 — extends to the solvents thymol and naphthalene, whose melting points are high, 48°·55 and 80°·10, as well as to water, benzene, etc.—*Comptes Rendus, June 7, 1886.*

TURBINES.

By J. Lester Woodbridge, M. E., Stevens Institute of Technology.
[With an Introduction by De Volson Wood, Professor of Mechanical Engineering.]

(*Concluded from November issue.*)

We will now use these equations to show some errors made by Rankine and Weisbach. Rankine, in his *Steam Engine and Other Prime Movers,* discusses a special wheel of the Fourneyron type, in which he assumes

$$a_2 = a_1, \text{ and } \gamma_1 = 90°.$$

These in equation (15) give

$$v_1 = \sin \gamma_2 \sqrt{\omega^2 \rho_2^2 - 2 \omega^2 \rho_1^2 + 2 g H} \qquad (25)$$

This velocity is radial along the vane, and is called by Rankine the "velocity of flow." The tangential component of the actual velocity must in this case be $\omega \rho_1$, and this, by Rankine, is called the velocity of whirl (v), and his value of v on page 196, equation (9) of the *Steam Engine* is not only incorrect but meaningless even for the turbine he considers.

From equation (15*a*) we also have

$$v_2 = \sqrt{\omega^2 \rho_2^2 - \omega^2 \rho_1^2 + 2 g H.} \qquad (26)$$

The expression for the efficiency becomes

$$E = \frac{\omega}{g H} \left[\omega \rho_1^2 - \omega \rho_2^2 + \rho_2 \cos \gamma_2 \sqrt{\omega^2 \rho_2^2 - 2 \omega^2 \rho_1^2 + 2 g H} \right] \cdot \qquad (27)$$

This expression differs entirely from Rankine's equation (10), page 196. But running this wheel at the same speed that Rankine does his, Art. 175; that is, making the final velocity of whirl zero, we have

$$v_2 \cos \gamma_2 = \omega \rho_2,$$

and equation (26) becomes

$$\omega \rho_2 = \cos \gamma_2 \sqrt{\omega^2 \rho_2^2 - 2 \omega^2 \rho_1^2 + 2 g H,}$$

from which we find

$$\omega = \sqrt{\frac{2 g H}{2 \rho_1^2 + \rho_2^2 \tan^2 \gamma_2}}; \qquad (28)$$

$$\therefore \omega \rho_1 = \sqrt{\frac{2\, g\, H}{2 + \frac{\rho_2^2}{\rho_1^2} \tan^2 \gamma_2}}.$$

which is the same as Rankine's equation (3), Art. 175. Substituting these in (27) we have

$$E = \frac{2\, \rho_1^2}{2\, \rho_2^2 + \rho_2^2 \tan^2 \gamma_2}$$

which is Rankine's equation (4), Art. 175.

We thus see that Rankine's equations not only do not fit any wheel except the one he is considering, but they apply to that only at one particular speed. These conclusions agree with those in an article on "Turbines," by Professor Wood, in the JOURNAL OF THE FRANKLIN INSTITUTE, for June, 1884.

In regard to the speed for maximum efficiency, Rankine, in the *Steam Engine*, Art. 173, says: "In order that the water may work to the best advantage, it should leave the wheel without whirling motion; for which purpose the velocity of whirl relative to the wheel should be equal and contrary to that of the second circumference of the wheel." As plausible as this appears, it is true only for special cases even for his wheel. Also, Weisbach makes the erroneous statement that the velocity of the second rim of the wheel should equal the relative velocity of discharge. Thus, in *The Mechanics of Engineering and Machinery*, Vol II., page 400, of the translation by Du Bois, he says (substituting my notation for his):

$$w = \sqrt{\omega^2 \rho_2^2 + v_2^2 - 2\, v_2\, \omega\, \rho_2 \cos \gamma_2}$$

$$= \sqrt{(\omega\, \rho_2 - v_2)^2 + 4\, \omega\, \rho_2\, v_2 \sin^2 \frac{\gamma_2}{2}}$$

in regard to which he states that for w a minimum $\omega\, \rho_2$ must equal v_2, which is not *generally* true, and is true only when $\gamma_2 = 0$, or when $v_2\, \omega\, \rho_2$ and $(\omega\, \rho_2 - v_2)^2$ happen to be a minimum together. The value of ω in equation (24) will in general satisfy neither Rankine's condition,

$$\omega\, \rho_2 = v_2 \cos \gamma_2, \tag{29}$$

nor Weisbach's,

$$\omega\, \rho_2 = v_2. \tag{29a}$$

Substituting in equation (24) Rankine's condition, $\gamma_1 = 90°$, and making $r = \frac{\rho_1}{\rho_2}$, we find

$$\omega^2 \rho_2^2 = \frac{g\,H}{1 - 2r^2} \left[\frac{1 - r^2 - \sqrt{(1-r^2)^2 - \cos^2\gamma_2\,(1 - 2\,r^2)}}{\sqrt{(1-r^2)^2 - \cos^2\gamma_2\,(1-2\,r^2)}}\right] \qquad (30)$$

and

$$v_2^2 = g\,H \frac{1 - r^2 + \sqrt{(1-r^2)^2 - \cos^2\gamma_2\,(1-2\,r^2)}}{\sqrt{(1-r^2)^2 - \cos^2\gamma_2\,(1-2\,r^2)}} \qquad (30a)$$

Substituting this in (15a) gives

$$v_2 \cos\gamma_2 = \omega\,\rho_2 \left[1 - r^2 + \sqrt{(1-r^2)^2 - \cos^2\gamma_2\,(1-2\,r^2)}\right]$$

This satisfies equation (29) only when $r^2 = \frac{1}{2}$, and (29a) only when $\gamma_2 = 0°$ or $r = 1$. The latter condition is that of a parallel flow wheel, or of an infinitely narrow wheel, in which cases we have

$$\omega\,\rho_2 = v_2 = \sqrt{g\,H}.$$

These in (17) give for the efficiency

$$E = \cos\gamma_2$$

which always exceeds the value given by Rankine,

$$E = \frac{2\cos^2\gamma_2}{2 + \cos^2\gamma_2},$$

except when $\gamma_2 = 0$, when both become unity, but the work done will be zero.

Making $\gamma_2 = 0$ in (24) and (15a), gives

$$\omega = \frac{\sqrt{g\,H}}{\rho_1}, \text{ and } v_2 = \frac{\rho_2}{\rho_1}\sqrt{g\,H};$$

$$\therefore\ v_2 = \omega\,\rho_2$$

for maximum efficiency, for this case, and the efficiency becomes unity.

In the case of Barker's mill, and the Whitelaw and other similar reaction wheels, we have $r = 0$, practically, and $\gamma_1 = 90$, and the angular velocity for maximum efficiency, equation (24), becomes

$$\omega\,\rho_2 = \sqrt{\frac{1 - \sin\gamma_2}{\sin\gamma_2} \cdot g\,H}$$

and the final velocity, (15*a*),

$$v_2 = \sqrt{\frac{1 + sin\ \gamma_2}{sin\ \gamma_2}\, g\, H}$$

When $\gamma_2 = 0$, as is usually the case, $\omega\ \rho_2$ and v_2 become infinite according to the preceding equations, which results agree with common analysis.

In the general analysis when $r > 1$, we have the inward flow wheel. As r becomes greater, $\omega\ \rho_2$ and v_2 continually approach 0 in value, and their ratio $\frac{v_2}{\omega\ \rho_2}$ approaches the limit, $cos\ \gamma_2$.

The value of the ratio

$$\frac{v_2\ cos\ \gamma_2}{\omega\ \rho_2}$$

indicates the direction of the final actual velocity. If that ratio be greater than unity, θ, *Fig.* 9, is obtuse. If less, θ is acute.

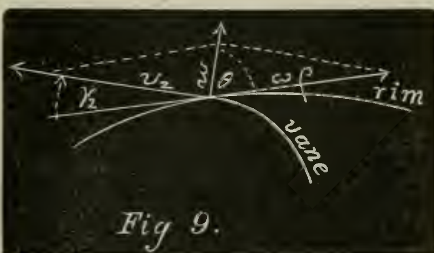


Fig 9.

Table I exhibits these various quantities at the critical points, assuming $\gamma_1 = 90°$.

TABLE I. ($\gamma_1 = 90°$.)

r	$\omega\ \rho_2$	v_2	$\frac{v_2 \cos \gamma_2}{\omega\ \rho_2}$	E
0	$\sqrt{g\ H\ \frac{1 - \sin \gamma_2}{\sin \gamma_2}}$	$\sqrt{g\ H\ \frac{1 + \sin \gamma_2}{\sin \gamma_2}}$	$1 + \sin \gamma_2$	$1 - \sin \gamma_2$
$\sqrt{\frac{1}{2}}$	$\sqrt{g\ H \cdot 2 \cos^2 \gamma_2}$	$\sqrt{2\ g\ H}$	1	$\cos^2 \gamma_2$
1	$\sqrt{g\ H}$	$\sqrt{g\ H}$	$\cos \gamma_2$	$\cos \gamma_2$
∞	0	0	$\cos^2 \gamma_2$	1

Table II gives the values of $\frac{v_2 \cos \gamma_2}{\omega \rho_2}$ and $\omega \rho_2$ for various values of r, assuming $\gamma_2 = 10°$, also the values of $\omega \rho_2$ deduced from Rankine's and Weisbach's conditions of maximum efficiency. Table III gives the same quantities when $\gamma_2 = 30°$.

TABLE II. ($\gamma_2 = 10°$.)

r	$\frac{v_2 \cos \gamma_2}{\omega \rho_2}$	$\omega \rho_2$ (Woodbridge.)	$\omega \rho_2$ (Rankine.)	$\omega \rho_2$ (Weisbach.)
0	1·174	$2·181 \times \sqrt{g H}$	$8·020 \times \sqrt{g H}$	∞
·2	1·131	$2·237 \times \sqrt{g H}$	$4·071 \times \sqrt{g H}$	$5·000 \times \sqrt{g H}$
·4	1·055	$2·070 \times \sqrt{g H}$	$2·387 \times \sqrt{g H}$	$2·500 \times \sqrt{g H}$
·6	1·012	$1·606 \times \sqrt{g H}$	$1·632 \times \sqrt{g H}$	$1·667 \times \sqrt{g H}$
·7	1·000	$1·393 \times \sqrt{g H}$	$1·393 \times \sqrt{g H}$	$1·414 \times \sqrt{g H}$
·8	·993	$1·242 \times \sqrt{g H}$	$1·235 \times \sqrt{g H}$	$1·250 \times \sqrt{g H}$
1·0	·985	$1·000 \times \sqrt{g H}$	$·992 \times \sqrt{g H}$	$1·000 \times \sqrt{g H}$
1·2	·980	$·835 \times \sqrt{g H}$	$·829 \times \sqrt{g H}$	$·833 \times \sqrt{g H}$
1·5	·976	$·668 \times \sqrt{g H}$	$·664 \times \sqrt{g H}$	$·667 \times \sqrt{g H}$
2·0	·974	$·500 \times \sqrt{g H}$	$·499 \times \sqrt{g H}$	$·500 \times \sqrt{g H}$
∞	·970	0	0	0

TABLE III. ($\gamma_2 = 30°$)

r	$\frac{v_2 \cos \gamma_2}{\omega \rho_2}$	$\omega \rho_2$ (Woodbridge.)	$\omega \rho_2$ (Rankine.)	$\omega \rho_2$ (Weisbach.)
0	1·500	$1·000 \times \sqrt{g H}$	$2·449 \times \sqrt{g H}$	∞
·2	1·441	$1·040 \times \sqrt{g H}$	$2·200 \times \sqrt{g H}$	$5·000 \times \sqrt{g H}$
·4	1·282	$1·150 \times \sqrt{g H}$	$1·750 \times \sqrt{g H}$	$2·500 \times \sqrt{g H}$
·6	1·087	$1·243 \times \sqrt{g H}$	$1·378 \times \sqrt{g H}$	$1·667 \times \sqrt{g H}$
·7	1·000	$1·225 \times \sqrt{g H}$	$1·225 \times \sqrt{g H}$	$1·414 \times \sqrt{g H}$
·8	·943	$1·168 \times \sqrt{g H}$	$1·113 \times \sqrt{g H}$	$1·250 \times \sqrt{g H}$
1·0	·866	$1·000 \times \sqrt{g H}$	$·926 \times \sqrt{g H}$	$1·000 \times \sqrt{g H}$
1·2	·826	$·846 \times \sqrt{g H}$	$·789 \times \sqrt{g H}$	$·833 \times \sqrt{g H}$
1·5	·796	$·678 \times \sqrt{g H}$	$·643 \times \sqrt{g H}$	$·667 \times \sqrt{g H}$
2·0	·775	$·506 \times \sqrt{g H}$	$·490 \times \sqrt{g H}$	$·500 \times \sqrt{g H}$
∞	·750	0	0	0

In *Fig. 10*, I have laid off the direction of the final actual velocity of the water for various values of r, taking the two cases $\gamma_2 = 10°$, and $\gamma_2 = 30°$, thus obtaining two curves, $O\,P'\,D\,K$, and $O\,P\,D\,L$. Taking any point P on one of these curves, $O\,P$ rep-

resents the value of r ($O\,A$ being unity), and $P\,O\,A$ the corresponding angle θ (see *Fig. 9*). $H\,E$ and $G\,F$ are tangents at the origin, and $O\,M$ and $O\,N$ are asymptotes to the two curves, respectively. All curves such as these will pass through the

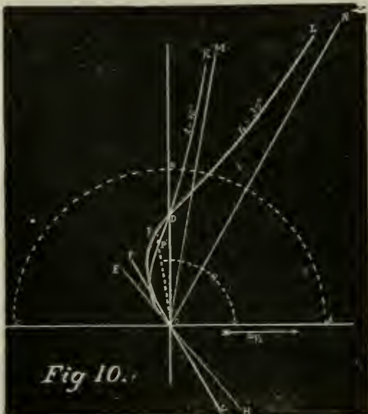


Fig 10.

point D, where $r = \sqrt{\frac{1}{2}}$, and the final velocity is radial for all values of γ_2 for this value of r. When $\gamma_2 = 0$, these curves reduce to the line $O\,B$.

In *Fig. 11*, I have plotted the values of $\omega\,\rho_2$, corresponding to

Fig 11

various values of r, for the condition $\gamma_2 = 30^\circ$, thus obtaining the curve $A\,P\,B$, and from Rankine's and Weisbach's conditions the curves $G\,H$ and $C\,D$, respectively. The abscissas represent values of r, $O\,M$ being unity, and the ordinates give $\omega\,\rho_2$, $O\,A$ being

equal to $\sqrt{gH}$. Rankine's curve intersects the true one at Q, where $r = \sqrt{\frac{1}{2}}$, Weisbach's is an equilateral hyperbola, and is independent of γ_2. It intersects the true curve at S.

The above discussion applies only to the case where $\gamma_1 = 90°$. Returning now to the general case, substitute in equation (18) the value of ω^2 from equation (24) and we have for the maximum efficiency of any frictionless turbine

$$E_{\max} = \frac{s^2 - \sqrt{s^4 - m^2 l^2}}{l^2} \tag{31}$$

This expression also involves the variables $\gamma_1, \gamma_2, \rho_1, \rho_2, a_1, a_2$. Putting $\frac{\rho_1}{\rho_2} = r$, and $\frac{a_2}{a_1} \cot \gamma_1 = f$, we reduce the number of variables to three. The complete discussion of this equation with reference to these three variables is too long and complicated for insertion here, and is not of much practical value. A few numerical results will show how the theoretical efficiency varies within the range of practice.

We observe first that the efficiency increases as γ_2 diminishes, and becomes unity when $\gamma_2 = 0$. But to insure a flow, γ_2 must have some value greater than 0. Letting $\gamma_2 = 30°$, we have the following tables.

TABLE A. (Values of the efficiency.)

f =	$-\infty$	$-.4$	0	$+.4$
$r = \sqrt{\frac{1}{2}}$	1·000	·800	·750	·671
$r = 1$	1·000	·888	·866	·832
$r = 2$	1·000	·970	·968	·965

TABLE B. (Values of $\omega\rho_2$)

f =	$-\infty$	$-.4$	0	$+.4$
$r = \sqrt{\frac{1}{2}}$	0	$1{\cdot}099\sqrt{gH}$	$1{\cdot}225\sqrt{gH}$	$1{\cdot}321\sqrt{gH}$
$r = 1$	0	$\cdot913\sqrt{gH}$	$\sqrt{gH}$	$1{\cdot}118\sqrt{gH}$
$r = 2$	0	$\cdot484\sqrt{gH}$	$\cdot506\sqrt{gH}$	$\cdot532\sqrt{gH}$

TABLE C. (Values of v_2.)

$f=$	$-\infty$	$-\cdot 4$	0	$+\cdot 4$
$r=\sqrt{\frac{1}{2}}$	0	$1\cdot 267\sqrt{gH}$	$1\cdot 414\sqrt{gH}$	$1\cdot 623\sqrt{gH}$
$r=1$	0	$\cdot 913\sqrt{gH}$	$\sqrt{gH}$	$1\cdot 118\sqrt{gH}$
$r=2$	0	$\cdot 438\sqrt{gH}$	$\cdot 453\sqrt{gH}$	$\cdot 479\sqrt{gH}$

TABLE D. (Values of θ. *Fig. 9.*)

$f=$	$-\cdot 4$	0	$+\cdot 4$
$r=\sqrt{\frac{1}{2}}$	90° 10′	90° 00′	84° 05′
$r=1$	75° 00′	75° 00′	75° 00′
$r=2$	64° 32′	63° 17′	64° 06′

The value $r=\sqrt{\frac{1}{2}}$ corresponds to an outward-flow wheel, $r=1$ to a parallel-flow, and $r=2$ to an inward-flow. The negative values of f occur when γ_1 is obtuse. In Table A, we see that the efficiency of the inward-flow wheel is greater than that of the outward-flow, other things being equal; and the efficiency is also increased by increasing the initial angle γ_1. When the latter becomes 180°, the efficiency becomes unity, but there is no flow. From

Fig 12.

Tables B and C, we see that for the parallel-flow wheel, $v_2=\omega\,\rho_2$ for all values of f, and the final actual direction of flow therefore bisects the external angle of the vane. In only one case is this flow radial. In the others, it has a tangential component, which is forward in nearly all the instances given above. It will be remembered that these tables apply to the wheel only when running at the speed of maximum efficiency.

In *Fig. 12*, let $A\,D$ be tangent to the wheel at its circumference,

$A\,C$ tangent to the guide-plate at its final element, and the angle between these tangents α, called the final angle of the guide-plates. Assume, as before, that this angle is so adjusted that the water will enter the wheel smoothly, then we have

$$V \cos \alpha = \omega \rho_1 - v_1 \cos \gamma_1 \qquad (32)$$

Combining this with (10), we have

$$\cos \alpha = \frac{\omega \rho_1 - v_1 \cos \gamma_1}{\sqrt{\omega^2 \rho_1^2 - 2\,\omega \rho_1 v_1 \cos \gamma_1 + v_1^2}} \qquad (33)$$

From this, v_1 could be eliminated by means of (15), and α expressed in terms of $a_1, a_2, \rho_1, \rho_2, \gamma_1, \gamma_2$, and ω. The first six of these quantities are fixed for any one turbine, while ω may vary. We thus see that our assumption in regard to α is equivalent to making that angle vary with every change in the angular velocity. This actually takes place to a certain extent by the piling of the water in the passages between the guides. Each turbine, however, is designed to run at a fixed speed, and, in order that this speed may be that of maximum efficiency, its dimensions and angles should be such as to satisfy equations (24), and the angle α should be determined from equation (33).

In order to discuss the pressure in the wheel, integrate equation (3) between the constant limits v_1, p_1, ρ_1, and the variable limits v, p, ρ, and find

$$\frac{1}{2}\,\omega^2 (\rho_1^2 - \rho^2) - \frac{1}{\delta}(p_1 - p) = \frac{1}{2}(v_1^2 - v^2) \qquad (34)$$

From (12) we have

$$\frac{p_1}{\delta} = \frac{p_a}{\delta} + g\mathfrak{h} - \frac{1}{2} v_1^2 - \frac{1}{2}\,\omega^2 \rho_1^2 + v_1 \omega \rho_1 \cos \gamma_1 \qquad (35)$$

Also from (9)

$$v = v_1 \frac{a_1 \sin \gamma_1}{a \sin \gamma},$$

and these in (34) give

$$\frac{p}{\delta} = \frac{1}{2}\,\omega^2 \rho^2 - \frac{1}{2}\,\omega^2 \rho_1^2 + \frac{p_a}{\delta} + 2g\mathfrak{h} + v_1 \omega \rho_1 \cos \gamma_1 - v_1^2 \frac{a_1^2 \sin^2 \gamma_1}{a^2 \sin^2 \gamma} \qquad (36)$$

This gives the pressure at any point in the wheel in terms of constants already known, and the variables ρ, a, γ, depending upon the construction of the wheel. There are two distinct cases to be considered:

(1.) That in which the discharge is into the free air;

(2.) That in which the wheel is submerged.

In the first case, if equation (36) shows a gradually decreasing pressure from the entrance to the exit of the wheel, that equation holds good practically. If the pressure be constant, the case is that of free deviation, in which *the pressure does no work* directly in the wheel. If, however, equation (36) shows a point of minimum pressure, less than p_a, from which point the pressure increases both ways, the equation, while theoretically possible, indicates a condition of unstable equilibrium, which could never hold in practice. The slightest inequality in the action of the wheel would cause air to rush in, up to the point of minimum pressure, which pressure would then become that of the atmosphere. The pressures in the wheel, and consequently the flow and the entire action of the water would thus be changed. The wheel must now be considered in two parts —within and without the point of minimum pressure; and hence this point must be found before the wheel can be analyzed. If we know a and γ as functions of ρ, we could make $\frac{dp}{d\rho} = 0$ in (36) and determine this point analytically. But if, as is usually the case, we do not know the relations between γ, ρ and a, we must determine it graphically by plotting a curve of pressures from equation (36), substituting values of a, ρ, γ, taken at various points in the wheel; v_1 being found from equation (15), as if the passages were full. The point of minimum pressure may be found from this curve.

From the entrance of the wheel up to this point, the analysis will be the same as if the rest of the wheel were removed, since the water beyond is free, and exerts no reaction on the water behind. The equations already given, therefore, apply, and the velocity of the water at this point, which we will call v_x, may be determined from (15a). Beyond this, we have the case of free deviation; the pressure will be constant and equal to p_a, and equation (6) becomes

$$\omega^2 \rho_x^2 - \omega^2 \rho_2^2 = v_x^2 - v_2^2 \qquad (37)$$

This gives v_2 directly, and from this the work done in this part of the wheel may be calculated and added to that previously found.

If the point of minimum pressure is at the entrance to the wheel, the case becomes wholly one of free deviation.

The second case, that in which the wheel is submerged, we see that, since the air has no chance to enter, the equations will apply; subject, however, to the condition that the pressure, as given by (36), never becomes negative, since this would imply a tensile resistance in water. If equation (36) makes p negative, analysis becomes impossible, since the flowing stream would not fill the passages beyond the point of minimum pressure, and the effect of cushion water and eddying on the pressure and velocity, would enter as indeterminate elements. Such a wheel would never, knowingly, be constructed, and the analysis would be useless if possible.

PRACTICAL DEDUCTIONS FROM THE FRANKLIN INSTITUTE TESTS OF DYNAMOS.*

By CARL HERING.

The tests of dynamo-electric machines, made in 1885, under the auspices of the FRANKLIN INSTITUTE, are undoubtedly the most reliable and complete of all the impartial tests which have ever been made and published, and they therefore afford the practical electrical engineer an excellent opportunity to deduce proportions, dimensions and constants, to assist him in designing dynamos, especially as the machines which were tested are among the best that are made, and represent the results of tedious and expensive experimenting on the part of the makers, while, at the same time, they embody the improvements suggested by long and continued use of the machines in practice.

Dynamos have frequently been built by "guessing" at the proportions, constructing them, and then trying them to "see what they will give." If they then turn out (by chance) to give the electro-motive force and current desired, the designer generally gets the credit for having made very correct "calculations;" while if they give, for some unknown reason, quite different results, the manufacturer has to be consoled with the statement that "it is not possible to calculate the parts of a dynamo"

If a machine is at hand which can be thoroughly tested and measured in all its parts, it is not difficult for a technical engineer,

* From the *Electrician and Electrical Engineer*, November, 1886.

	Reference Letter.	Edison No. 4.	Edison No. 5 or *T.*	Edison No. 10 or *S*,	Edison No. 20 or *H*.	Weston 6 *M*.	Weston 6 *W I*.	Weston 7 *M*.
External diameter of armature in inches, ...	*a*	7.063	7.875	10.625	10.625	8.031	8.250	9.375
Internal diameter or diameter of the core, ...	*b*	6.250	7.063	9.688	9 688	7.387	7.410	8.595
Mean diameter in inches, ...	*c*	6.657	7.469	10.156	10.156	7.709	7.830	8.985
Speed in revolutions per minute, ...	*d*	1600.	1400.8	1208.6	1092.1	1114 9	1257.6	1043.5
Mean inductor velocity in feet per second, ...	*e*	46 5	45.6	53.6	48.2	37.4	43.0	41.0
Number of coils or commutator-bars, ...	*f*	50	50	64	44	72	56	64
Number of turns per coil, ...	*g*	2	2	1	1	2	2	2
Total number of turns on armature, ...	*h*	100	100	64	44	144	112	128
Mean distance between pole-piece projections in inches, ...	*i*	2 69	2.313	3.50	4.88	2.52	2.58	2.94
Active part of circumference of armature in per cent. (approx.), ...	*j*	76	80	80	71	80	80	80
Length of pole-piece or armature-core in inches, .	*k*	12.	13.	16.5	29.5	14	14	16.5
Total E. M. F. in volts, ...	*l*	131.91	131.5	129.35	129.60	127.17	136.22	165.58
Mean induction in volts per foot, ...	*m*	1.733	1.515	1.838	1.687	.948	1.304	1.175
Volts per foot for one foot per second, ...	*n*	.0373	.0332	0343	.0350	.0254	.0303	.0287
Mean intensity of field, in lines of force per square inch, ...	*o*	25900.	23000.	23800.	24260.	17630.	21000	19900.
Amount of magnetism in field, in lines of force, .	*p*	2660000	3090000.	5250000.	8600000.	2490000.	3042000	3860000.
Energy in field in horse-power, ...	*q*	.394	.401	.675	.862	.207	.402	.498
Useful lines of force per volt-ampère in field, (relative efficiency of field), ...	*r*	90.2	103 1	104.1	133.5	161.1	101.5	103.7
Length of wire in one coil in inches, ...	*s*	92.	102.	68.	98.	154.	151.	160.
Total length of armature wire in feet (parallel wires considered as one), ...	*t*	383	425	363	359	924	705	853
Available active length in feet, ...	*u*	152 0	173.4	140.8	153.6	268.8	209.0	281.6
Percentage of total, which is active.	*v*	40	41	39	43	29	30	33
Diameter of bare armature-wire in inches, ...	*w*	148	.180	.199	.199	.141	190	.275
Number of wires in parallel, ...	*x*	1	1	2	3	1	1	1
Total current in armature, ...	*y*	84.42	103.31	205.50	392.42	72.84	100.60	128.16
Square mils of cross-section per ampère, ...	*z*	407	492	606	475	428	562	374
Percentage of energy in armature, ...	*A*	3 70	4.65	3.12	3 39	5.43	3.09	5.59
Total electrical energy in horse-power, ...	*B*	14 93	18.23	35.67	63 25	12.43	18.39	28.47
Relative efficiency of armature as an inductor, .	*C*	11.33	8.44	7.90	10 17	4.32	4.62	6.94
Useful commercial efficiency of machine, ...	*D*	88.38	89.76	89 70	91.90	87 38	90.21	89.92
Depth of winding in inches, ...	*E*	.407	.406	.469	.469	.322	.420	.390
Percentage of diameter taken up by windings, . .	*F*	11.5	10.3	8 83	8.83	8.02	10.2	8 32
Distance between pole-piece projections divided by depth of windings and clearance, ...	*G*	5 0	4.4	5.9	8.2	5.65	4.75	5.72
Ratio of length to diameter of armature-core, . .	*H*	1.9	1.8	1.7	3.0	1 9	1 9	1.9
Ratio of length to diameter of bearings, ...	*I*	4.2	4 3	4.1	4.1	4.2 & 3.6	4 2 & 3 6	3.8 & 4.3
Volts per commutator-bar, ...	*J*	6.7	6 25	4.9	7.2	4 2	5 9	6.1

who is well informed concerning the principles and practice of dynamo building, to calculate the parts of another machine of the same type which will give a certain desired electro-motive force and current slightly different from that of the first machine. But when the designer has no access to such a model machine, or if the current and potential desired differ greatly from those of the model, it is difficult, if not quite impossible, to calculate with any degree of certainty the parts of a dynamo from the principles and laws of induction and resistance, without some practical constants and proportions, which can be obtained only from existing machines.

As an aid and guide in such calculations, a set of practical constants and proportions have been calculated by the writer from the valuable tests of the FRANKLIN INSTITUTE. These constants will not only materially diminish the amount of "guessing" in designing machines, but it is believed they are sufficiently complete to enable a technical engineer to calculate all the electrical proportions of a well-designed cylindrical armature which is to give a certain required electro-motive force and current. It is to be regretted that the data given in the FRANKLIN INSTITUTE Report are not sufficient to enable a similar complete set of constants to be deduced for the field. A few of these may, however, be calculated, and they will materially aid in determining certain parts of the field. The calculations of armatures being based on induction and conductivity, the constants from one armature may be used in calculating others; but in the field this is not the case, as the relation between the exciting current and the magnetism produced depends very largely on the size, shape and proportions, of the coils and the iron parts, including the cores, the so-called neutral parts, pole-pieces, etc., as well as on the quality of the iron. As these are so very different in different machines, the constants obtained from one would be of little use in determining the size of other fields, except, perhaps, the constants given below for the intensity and amount of the magnetism of the field. A careful and systematic builder of dynamos will, in most cases, run the armature, when completed, with its own field magnet frame with temporary, removable coils of known number of turns, on the magnets, in order to find, by regulating the current in these temporary field coils, how many ampère-turns are required in the field to induce

the desired electro-motive force and current in the armature. From this number of ampère-turns any competent dynamo builder can readily calculate the proper windings of the magnets with all due accuracy.

Numerous theories of dynamo-electric machines have been advanced, but most of them are of greater interest to the mathematician and the physicist than to the practical dynamo builder. More attention seems to have been given to integrals, complicated abstruse fractions and formulæ for determining the presumably correct values for extreme impossible cases, than to simple, practical formulæ, by means of which tangible results may be obtained for the ordinary forms of machines. In some cases, formulæ based on physical theories have been suggested, which might have been of practical use if accompanied by the absolute and reliable values of certain constants usually represented by Greek letters, which enter as direct factors in the formulæ; but the values of these constants have either been omitted, or else have been given within such wide ranges that they cannot be used to any advantage in practice. They are sometimes of such a nature that they differ for each machine, thus necessitating the construction and testing of the machine before the values of the constants for calculating this particular machine may be determined; which is, to say the least, a very awkward way of applying a formula.

The writer has, therefore, set aside all abstruse theories of the dynamo, which have yet to stand the severe test of varied practical application, and has endeavored to deduce from the results given in the Franklin Institute Report some constants, or values, which are in such a form that they may be directly applied to the calculations of the armature and some parts of the field. The deductions of these constants are based only on the well-known laws of induction and of mechanics, and as they are calculated from actual cases, they show what *is* done in practice, as distinguished from what *might be* done according to some theory, provided the theory is correct.

The results tabulated on the following page not only give the values which can be used in designing machines, but an attempt has also been made to determine the efficiency of separate parts; thus indicating under what circumstances the most advantageous proportions may be arrived at. Some proportions used in calcu-

lating the numbers given in the table were not contained in the report, and, therefore, had to be estimated, except where they were furnished to the writer by the kindness of the manufacturers. But the errors which may have been introduced by a slightly inaccurate estimate, are so small that they do not materially affect the results. Certain slight errors, or modifications, in some of the figures, or proportions, were not taken into account, as they cannot be determined; but they are of such a nature as to affect equally, or approximately so, all machines not differing too widely from the style of those tested. Among these is the self-induction of the armature; in well-built machines, like those tested in which the field is intense, the speed not too high, the number of commutator bars or coils large, and the number of windings per coil very small, the self-induction will be very small, and, therefore, the difference between the self-induction in these different armatures may be neglected.

In the table given below, the deduced constants have been accompanied by many of the proportions from which they were derived, as copied from the report, in order to show some of the principal proportions of the machines, and to give the conditions under which the constants have the values given. Numerous other values in the report might have been repeated here, but as it is presumed that any one can obtain the original report, they are omitted.* The values chosen for the deductions were taken from that one of the full load tests in which the current and potential were nearest to the values given by the makers as the best working load. (*See Table.*)

The following assumptions were made, as the accurate data for deducing the same were wanting. The speed in the Edison No. 4 machine was not given in the report; that given here is the speed at which the makers say the machine is to be run, and it is assumed that the speed must have been very nearly this in the test. The percentage of the whole circumference of the armature which is embraced by the pole-pieces was, in the Weston machines, assumed to be about eighty per cent., as this was the proportion in some arc-light machines of the same makers, which we understand have the same type of frame. The distance between the pole-piece

* For the full report, see this JOURNAL Supplement, November, 1885.

projections was determined from this in the Weston machines. In the Edison machines, the length of the pole-pieces and the armature-core, were deduced from the statement in the report giving the length of useful wire in a coil; it was assumed that by the term, "useful wire," was meant that which lies directly between the pole-pieces and the armature-core. In the Edison machines, it was assumed that the length of the armature-core was the same as that of the pole-pieces; in the Weston machines, this was the case.

As the electro-motive force induced in an armature is dependent upon the amount of magnetism passed through per second, the first questions in designing armatures are: How great may the velocity of the moving wire be? What must its length be? What must the intensity of the field be? etc.

The first of these, the velocity of the moving wire—commonly called the "conductor or inductor velocity"—depends on the distance of the active wire from the centre of the shaft, and on the number of revolutions of the armature. It may be calculated from the speed and the mean of the external diameter and the diameter of the core. In the accompanying table, the horizontal column *a* contains the external diameters, *b* the internal, and *c* the mean. From this mean value the circumference in feet was calculated, which, when multiplied by the speeds *d*, and reduced to seconds, gives the inductor velocities in feet per second, in column *e*. From these values, it is seen that the Edison armatures have a higher velocity of the moving wire; also, that it is preferable to obtain the high inductor velocity by making the diameter as great as practical, rather than to increase the number of revolutions, as will be seen by comparing the small, high-speed armature of the Edison No. 4 with the large one of the Nos. 10 and 20.

To obtain a constant by means of which the length of wire may be calculated, the total electro-motive force in volts which was generated, has been divided by the length of that part of the wire in which it is generated. This wire will be termed the "active wire," and, in these deductions, has been limited to that portion of the armature-wire which lies directly between the pole-pieces and the armature-core. Strictly speaking this is not quite correct, as some induction does undoubtedly take place in some parts of the wire lying at the ends of the armature, and also in some of the longitudinal wires which are not directly between the armature-core and

the pole-pieces; but the induction in both of these parts is presumably so small as compared to that in other parts, that it may be neglected, especially as the constants are to be applied to similar armatures, thus eliminating this error. The length of the active wires were calculated from the following proportions. Column *f* gives the number of coils or commutator-bars; *g* the number of turns per coil, and *h* the resulting total number of turns on the armature. The proportion of these coils which are active, is calculated from the distance between the pole-piece projections, column *i* and the circumference determined from the diameters in column *a*; the ratio of this is given in column *j*, in percentage of the circumference of the armature which is active; this will also represent the percentage of the number of windings which is active. Column *k* gives the length of a pole-piece in inches, which is the same as the length of the armature-core. From these the total length of the active wire in feet can be calculated, remembering that every turn of wire on the armature represents twice the length of the pole-piece; but as the two valves of the armature-wires are in multiple arc only half of this induces the whole electro-motive force. The total electro-motive force in volts, given in column *l*, is then divided by this half length of active wire in feet, giving the induction in volts per foot in column *m*. As this induction is slightly different in different positions of the wire with reference to the pole-pieces, these results give the mean value. They show that the induction is considerably higher in the Edison than in the Weston machines; also, that it is very nearly the same in all the Edison, and nearly the same in the three Weston machines.

These constants are dependent on the velocity of the inductor, for it is evident that if the latter were higher the induction would be increased. In order, therefore, to properly compare these constants, it is necessary to eliminate the velocity by dividing these figures by the velocities in column *e*, thus giving the volts per foot which would be induced (in the respective fields) at a uniform velocity of one foot per second. This is given in column *n*, and shows the number of volts induced per foot for an inductor velocity of one foot per second. These may be compared with each other as the velocities are the same. They show that at the same velocity the induction is better in the Edison than in the Weston machines; also that the values agree very closely for all the Edison,

except for the No. 4 machine, which may possibly be attributed to the number assumed for the speed, which was not taken in the test. For the Weston 6 M it is lowest, which is no doubt due to a less intense field.

The next question which naturally arises is, what was the intensity of the field in these machines? This may be determined as follows: We know that a volt is 100,000,000· times the unit of electro-motive force in the absolute system, and also that one absolute unit of electro-motive force is generated when a wire cuts lines of force at the rate of one per second; therefore one volt is induced if a wire cuts 100,000,000· lines of force per second. As we know the number of volts in one foot (column *m*) in these machines, and also the number of feet moved through in one second (column *e*), we can readily calculate the intensity which the field must have had to induce that number of volts in one foot. To illustrate this, suppose the velocity was one foot per second, and that the induction was one volt per foot at this velocity, then it is evident that the surface moved over by one foot of wire in one second; that is, one square foot, must contain 100,000,000· lines of force; or, if the induction was two volts per foot, there must be 200,000,000· lines if force in this space, as this number must have been cut per second to generate two volts. Dividing this number by 144, will give the mean intensity of the field in number of lines of force per square inch. These figures are given in column *o*. They show that with one exception, all the Edison machines have very nearly the same intensity of field; also, that it is somewhat lower in the Weston, especially in the 6 M machine; but, as will be seen, it is more economically obtained in this one, which indicates that it was probably not over saturated.

These values might also have been obtained by multiplying those in column *n* by 100,000,000· and dividing by 144, which is equivalent to multiplying them by 694,444. This will be seen by considering the principles of the deductions.

The total useful amount of magnetism in the whole field is evidently the intensity per square inch multiplied by the size of the field in square inches. As the intensity has been calculated from the amount of induction, the amount of magnetism thus obtained does not include the leakage of the magnetism; that is, those lines of force which are not cut by the armature-wire, it therefore

represents the useful magnetism only. The same lines of force which enter the armature at one pole-piece pass through it to the other pole-piece, and therefore the total number of lines of force is the intensity multiplied by the curved area of one pole-piece. These figures are given in column *p*, and are deduced from columns *o*, *a*, *j* and *k*. The magnetism increases with the number of volt-ampères which the machine generates.

This amount of magnetism is generated at the expense of a certain quantity of electrical energy in the field magnets. In order to get some approximate values for calculating roughly how much electrical energy will be required for generating in practice, a certain amount of magnetism in similar fields, the figures in column *p*, may be divided by the amount of energy in volt-ampères, that was required in these cases to generate the respective fields. In the report the figures in column *q*, are given, which are the energy in horse-power consumed in the fields. Unfortunately the resistance of the field without the regulator-box was measured only in one machine, so that the energy given here represents more than that used in the field-magnets themselves, thus introducing an error in all the deductions made from these values. It is presumed, however, that at full load the resistance in the box was not large, so that the error will probably be small. Reducing this energy in the field to volt-ampères and dividing it into the amount of magnetism, gives the number of useful lines of force generated per volt-ampère in the field. These are given in column *r*. As they depend on so many different proportions of the parts of the field and magnet-coils, and also in a measure on the armature, they might vary considerably for different types of field-magnets, and can, therefore, be used only in making rough preliminary calculations. They agree tolerably well for these fields, except for the Weston 6 M, which is evidently better proportioned than the others. As these figures are the ratio of that which is produced to that which is required to produce it, they may be said to represent the *relative* efficiencies of the different fields, in which sense they represent no absolute efficiencies, but serve simply to compare the efficiencies with one another. In the Edison machines, we believe wrought-iron alone is used, while in the Weston both wrought and cast iron were formerly used together, and we presume were used in these machines also. Possibly the iron in the field of the Weston

6 M machine is not over saturated, which may be the reason of its high efficiency of field.

The wires of the armature being wound repeatedly around it, pass through the same field a number of times, thus utilizing the same field in one revolution for successive inductions in the same wire. This number of turns, as given in column *h*, multiplied by column *j*, may therefore be said to represent the economic use of the field; it does not follow, however, that the best armature is the one having the greatest number of turns on it, as it is quite the reverse, other more important considerations, such as self-induction, sparking, etc., require that the number of turns of wire be as small as practicable.

In deducing the number of volts per foot, only the active wire was taken into consideration. In designing armatures it is therefore necessary to know what the proportion is between the active and the total length of the wire, for if the active length is determined first from the number of volts to be generated and the induction per foot, we must find what the total length is in order to determine the resistance or cross-section of the wire. This proportion of active to total length will evidently depend on several dimensions of an armature, and will, therefore, vary somewhat in different machines. For these machines it was determined as follows: column *s* contains the mean length of wire in one turn (where several smaller wires are in parallel they were considered as one); this multiplied by the number of coils in column *f*, gives the total lengths in column *t*; these divided into the active length in column *u*, give the percentage in column *v*. From the latter it will be seen that the economy of the wire is considerably better in the Edison than in the Weston, and that it is best in the Edison No. 20, the proportion between the length and diameter of the armature being greatest in this one. Most of the proportions from which these percentages have been deduced were given by the makers.

The density of the current in the armature-wire can be determined from the diameters of the wire in column *w*, the number of wires in parallel in a coil, in column *x*, and the total current in the armature in column *y*. Dividing the latter into the double area of cross-section of the wire in square mils, or the double sum of the cross-sections of the parallel wires, gives the number of square

mils per ampère in column *z*. These numbers vary somewhat with the current and with several other proportions; they should, therefore, be used only as a general guide, or for making preliminary calculations. The best method for determining the cross-section, is to find the resistance from the amount of energy which is allowed to be lost in the armature, which together with the total length of the wire as determined from the induction per foot, etc., gives the required cross-section.

The percentage of energy in the armature as taken from the report, is given in column *A*. Those in which the loss is least, Weston 6 WI and Edison No. 10, have the greatest area of cross-section of wire per ampère (column *z*), while the one in which the loss is greatest, Weston 7 M, has the least cross-section per ampère. This relation does not necessarily exist between them all, as the percentage of loss depends also on the induction per foot of wire, and therefore on the length of the wire.

The relative efficiencies of these armatures, as inductors, may be seen from the figures in column *C*. The efficiency as an inductor, apart from that as a converter of energy, is greater the larger the total amount of electrical energy induced (column *B*), and the less the amount of wire necessary to effect this induction; it may, therefore, be expressed by the quotient of the two. The figures in column *C* have, therefore, been calculated by dividing those in column *B* by the lengths in column *t* and by the double area of cross-section determined from columns *w* and *x*, the decimal point being changed to reduce them to a convenient form. By themselves these figures represent nothing, but by comparing them with one another they show which of the armatures are the best proportioned as inductors. They show that the Edison are considerably better proportioned than the Weston. The most efficient armature is, strange to say, the smallest one, Edison No. 4, which is no doubt due to its having the most intense field (column *o*), the highest speed (column *d*), and almost the smallest cross-section of wire per ampère (column *z*); this higher efficiency is, however, obtained at the expense of the efficiency of the field, as will be seen from column *r*; the useful commercial efficiency of the whole machine is, therefore, below the average, as seen from column *D*. Next to this armature, in point of efficiency as an inductor, is the largest one, Edison No. 20; its high efficiency is no doubt due to

the great intensity of field (column o), the very small amount of wire on the armature (column t), the relatively high inductor velocity (column e), the large proportion of active wire (column v), and the comparatively small cross-section of the wire, per ampère (column z). The field of this machine has next to the highest efficiency as seen in column r, and therefore, as might be inferred, the machine has the best useful commercial efficiency of all of those tested, as seen in column D. It may be interesting to mention here that in this machine which has the best efficiency, the armature-wires cut the field less frequently than in any other, as seen from the number of turns in column h.

Another proportion which may serve as a guide in designing armatures, is the relation between the outside diameter of the armature and the diameter of the core, or what amounts to the same thing, the percentage of the external diameter which is taken up by the wire on both sides. These figures are given in column F, and are obtained by dividing twice the depth of the windings given in column E by the external diameter in column a. This is greatest in the smallest armature, Edison No. 4, showing another disadvantage of small armatures; it is least and therefore best, in the Weston 6 M, which may partially account for the economic field shown in column r, as the latter depends on this non-magnetic space.

A few other proportions may be deducted from the data given. One of these is the proportion of the distance between the pole-piece projections and the distance between the pole-pieces and the armature-core. This proportion should evidently be as great as practicable. The figures are given in column G and are obtained from columns i and E, allowing about $\frac{1}{16}$ of an inch for clearance on each side. It is greatest for the largest machine, Edison No. 20, which may partially account for its economic field in column r. The reciprocals of one half of the numbers in column G may be said to represent approximately the intensity of the leakage of magnetism, as compared to the intensity of the useful field at these places, as the lines of force have the choice of these two paths. But this will be only a rough approximation as a field is always more intense at points or sharp edges.

Another useful proportion is the relation between the length and diameter of the armature-core, as deduced from columns k

and *b*. It is given in column *H*, which shows by comparison with column *v* the advantage of a long armature. The Weston machines appear to be quite uniform in this respect, the length being almost twice the diameter.

Column *I* gives the relation between the length and diameter of the bearings.

Column *J* gives the electro-motive force between two neighboring commutator-bars. If this is great enough to maintain an arc across the insulation of the commutator-bars (about twenty volts) there is danger of starting the well-known flash, encircling the whole commutator, if the brushes should be misplaced sufficiently far to start the arc. It will be seen to be far within the limit of twenty volts in all of these machines.

The Edison Nos. 10 and 20 machines afford a good opportunity to compare two armatures of different lengths, but having all the other sizes and proportions alike, including the number of windings, size of wire, depth of winding, etc., only that in the one three wires are connected in parallel, and in the other, two; and that in the No. 20 the distance between the pole-piece projections is greater, making a difference of about ten per cent. in the number of active wires in favor of the smaller one. The chief gain of the long armature is seen in column *v*, in which it has the highest percentage, which partially accounts for the efficiency in column *C*, and the consequent commercial efficiency in column *D*.

The subject of self-induction of the armature was purposely omitted here, partly because insufficient data are given in the report to make any practical deductions regarding it, but principally because it is presumed that the self-induction in such armatures as these, with very few turns, is so small that it may be neglected in such rough values as have been deduced here. It is to be regretted that the resistance of the field-coils without the regulator-box was not measured in each case in order that the effect of the self-induction of the field-coils in increasing the apparent resistance could be calculated, and its relation to the number of pulsations or commutator-segments determined. In only one case was the field-resistance measured alone, and from this a calculation shows an increase of resistance of less than one-tenth of one per cent., and, therefore, probably less than the allowable error in measurement.

The fact that the Edison Nos. 5 and 20 machines gave way in the armature insulation will not lessen the value of these deductions to the designer of dynamos, as this was presumably a defect in the details of construction, and not in the proportion of parts.

The test of the Edison No. 20 machine was marked unofficial in the report because the preliminary run of ten hours was not on full load; but it is no doubt sufficiently accurate for the deductions of the approximate values in the table.

The deductions made here are not for the purpose of comparing the commercial value of these machines, as it has been shown in the tests that they are practically equal electrically. The most important consideration in this respect would be the cost of the machines and the cost of maintenance and attendance, which cannot be considered here.

For the benefit of any one not familiar with these machines, it may be added that they are all simple shunt machines, with cylinder armatures.

In conclusion, it may be said that the values deduced in the table may not be free from small errors, as great accuracy was not possible in all cases, owing to the want of some few detail dimensions; moreover, great accuracy has no particular value in such general deductions as these.

ANT-INHABITED PLANTS.—Hernandez, about the middle of the seventeenth century, described the stipular thorns of *Acacia cornigera* of Central America, into which certain ants eat, feed upon the pulpy interior, and live in the dwelling thus made. Such inhabited thorns grow larger and distorted, and the ants seem to pay for this hospitality by protecting the tree from other marauding insects. Two woody *Rubiaceæ* of Sumatra, were described in 1750, by Rumphius, as inhabited by ants. They are both epiphytic and attached to the host tree by a large tuberous base, which is cavernous and occupied by ants. The ants, by their irritating presence, cause the tuberous growth to enlarge, but the enlargement begins during germination, before the ants attack it, an instance of a plant preparing beforehand for expected guests. It is said that seedling plants which fail to become inhabited, perish. Dr. Gray, in a review, says that "it is most supposable that this extraordinary formation was acquired gradually; that the normally fleshy caulicle of the ancestral plant, made a nidus for an insect, developed under the disturbing stimulus somewhat as a gall develops until at length the tendency became hereditary, and the singular adaptation of plant to insect was established."—*Botan. Gazette, September and October, 1885.*

ADAM SCHAEFER'S COMPOUND FOR IMPROVING THE QUALITY OF STEEL.

By S. Lloyd Wiegand.

[*Abstract of a Communication, presented at the Stated Meeting of the* Institute, *held Wednesday, October 20, 1886.*]

This compound is the subject of letters-patent of the United States, numbered 341,173, and dated May 4, 1886. It consists of rosin, linseed-oil, glycerine and powdered charcoal, heated and intimately mixed in the proportions stated in the specification.

It is used by heating the steel to a clear red heat, and immersing and coating it in the compound, and the steel is afterwards re-heated and hardened in the usual manner by quickly cooling it.

Burned cast-steel is restored to its original condition, and the softer grades of steel acquire the properties of cast-steel by being treated as above stated. Tools made from Bessemer steel, which is incapable of being hardened, are, after treatment with this compound and hardening, capable of cutting cast-steel.

Tools so treated possess a greater durability than before, and are capable of cutting castings, which resist the best of ordinary cast-steel tools.

The grain of steel exhibited by fracture of tools so treated as compared with the same material before treatment shows a difference analogous to that between fine cast-steel and coarse or blistered steel.

The compound applied to gray castings and malleable iron-castings imparts a degree of hardness to them superior to ordinary case-hardening.

It is not attended in use with the unpleasant and deleterious fumes incident to case-hardening compounds, containing hydrocyanic acid, and is much less expensive.

Specimens of different materials in their normal state and also as treated with this compound and hardened were submitted, properly labelled, which conveyed a clearer conception of the effect than could be stated in language.

In order that the facility of application and its effect may be seen, a forge with fuel and bars of steel and other metal and a supply of the compound were submitted, by means of which

the members who felt inclined, personally tested it after the close of the meeting.

The compound has been introduced into practical use in many manufacturing establishments in this city with uniformly satisfactory results.

The CONSTITUENTS of COAL-TAR.*

By Alfred H. Allen F. I. C., F. C. S., of Sheffield, England.

The following table gives the names and formulæ of the numerous bodies, the pressure of which in coal-tar may be considered to be fairly well established, while other more volatile products of the distillation pass wholly into the gas. The presence in coal-tar of certain other compounds, which do not appear in the table, is strongly suspected; while of the constituents of the large fraction of coal-tar distilling between 240° and 270° C., and of the anthracene oils, much still remains to be learned. Of the composition of the residue or pitch still less is known.

The figures appended to the names of the constituents are their boiling points on the Centigrade scale. In the case of most of the compounds of very high boiling point, the melting points are also added.

The general composition of the various fractions obtained by the distillation of coal-tar will be regulated chiefly by the boiling points of their leading constituents, but the vapor-densities, vapor-tensions and relative abundance of the constituents of the tar also largely affect their behavior in the still. Thus, naphthalene is found in notable quantity in all the fractions from second light oils to anthracene oil, and is even deposited from the purified illuminating gas itself.

A Mushroom Developed in Human Saliva.—M. Galippe, having filtered saliva by means of Pasteur's apparatus, the filtered saliva remaining undisturbed, saw appear at the lower end of the filter, not in contact with the saliva, a mushroom made up of tubes of mycelium and of spores. By the advice of Prof. Max Cornu, M. Galippe has cultivated this mushroom in Van Tieghem cells and has been able to prove that it was neither an aspergillus, nor a penicillium. This fungus, which has neither been described, nor drawn heretofore, belongs to the monilia family. M. Galippe proposes to give it the name of Monilia sputicola.—*Comptes Rendus, May 24, 1886.*

* From an advance-sheet of the new edition of the author's work on *Commercial Organic Analysis.* Vol. II.

TABULAR VIEW OF THE CONSTITUENTS OF COAL-TAR.

	Paraffin Series, $C_n H_{2n+2}$.	Olefin Series, $C_n H_{2n}$.	Crotonylene Series, $C_n H_{2n-2}$.	Benzene Series, $C_n H_{2n-6}$	Naphthalene and its Allies.	Hydrocarbons of other Series.	Nitrogenized Bodies.		Oxygenated Bodies.	Sulphur Compounds.
Constituents of Crude Naphtha or Light Oils, distilling below 180°.	C_4H_{10}, Butane, + 1		C_4H_6, Crotonylene, 23					H_3N, Ammonia		(C_2H_6S, Methyl sulphide, 41)
	C_5H_{12}, Pentane, 38	C_5H_{10}, Amylene, 39	C_5H_8, Terene							($C_4H_{10}S$, Ethyl sulphide, 91)
	C_6H_{14}, Hexane, 69	C_6H_{12} Hexylene, 67	C_6H_{10}, Hexoylene, 80	C_6H_6, Benzene, 81		C_6H_{12}, Hexahydrobenzene, 69	C_2H_3N, { Methyl isocyanide, 60; Acetonitrile, 81 }		C_2H_6O, Alcohol, 78	(C_2H_6S, Ethyl sulphydrate, 36) CS_2, Carbon disulphide, 46
	C_7H_{16}, Heptane, 97	C_7H_{14}, Heptylene, 96		C_7H_8, Toluene, 111		C_7H_{14}, Hexahydrotoluene, 97 C_8H_{16}, Hexahydrometaxylene, 118	$C_4H_{11}N$, Butylamine, 75 C_4H_5N, Pyrroline, 130		H_2O, Water, 100	C_4H_4S, Thiophene, 84 C_5H_6S, Thiotolene, 113
	C_8H_{18}, Octane, 124 (C_9H_{20}, Nonane, 146)			C_8H_{10}, Xylenes, { *p.* 136; *m.* 138; *o.* 142 }		—		C_5H_5N, Pyridine, 116 C_6H_7N, Picoline, { *o.* 124; *m.* 140 }	$C_2H_4O_2$, Acetic acid, 119	C_6H_8S, Thioxene, 137
				C_9H_{12} { Mesitylene, 163; Pseudocumene, 166 }		C_8H_8, Cinnamene, 145		C_7H_9N, Lutidine, 154		
	$C_{10}H_{22}$, Decane, 167					C_9H_{14}, Nonone, 174		$C_8H_{11}N$, Collidine, 170		
Constituents of heavy, dead, or Creosote Oils, distilling between 180° and 290° C.				$C_{10}H_{14}$, Durene, 190	$C_{10}H_{12}$, Naphthalene tetra-hydride, 190		C_7H_7N, Aniline, 182	$C_9H_{13}N$, Parvoline, 188	C_6H_6O, Phenol, 182 C_7H_8O, Cresols, { *o.* 186; *m.* 198; *p.* 201 }	
					$C_{10}H_{10}$, Naphthalene dihydride, 200–210			$C_{10}H_{15}N$, Coridine, 211	$C_8H_{10}O$, Xenol, 212	
					$C_{10}H_8$, Naphthalene, 218, m. p. 79				($C_9H_{12}O$, Cumenol)	
					$C_{11}H_{10}$, Methylnaphthalene, { α 242; β 241 }		C_9H_7N, Leucoline, { 220; 238 }	$C_{11}H_{17}N$ Rubidine, 230		
					$C_{12}H_{12}$, Dimethylnaphthalene, 252–270	$C_{12}H_{10}$, Diphenyl, 254, m. p. 70·5	$C_{10}H_9N$, Lepidine, { 254; 268 }	$C_{12}H_{19}N$, Viridine, 251 } Pyridine bases.	C_7H_6O, Benzoic acid, 250, m. p. 120	
						($C_{12}H_{12}$, Acetnaphthene dihydride, 260)	$C_{11}H_{11}N$, Cryptidine, 272			
						$C_{12}H_{10}$, Acetnaphthene, 285, m. p. 95 $C_{13}H_{10}$, Fluorene, 295, m. p. 113	$C_{12}H_{13}N$, Tetracoline, 292		$C_{10}H_8O$, Naphthol, { α 278–280; β 285–290 }	
Constituents of Green or Anthracene Oils, distilling above 290°.						$C_{14}H_{16}$, Anthracene hexahydride, 290, m. p. 63	$C_{13}H_{15}N$, Pentacoline, 312 } Leucoline bases.			
						$C_{14}H_{12}$, Anthracene dihydride, 305, m. p. 106	$C_{14}H_{17}N$, Hexacoline, 327	$C_{12}H_9N$, Carbazol, 355, m. p. 238		
						$C_{14}H_{10}$, { Phenanthrene, 340, m p. 99; Synanthrene, m. p. 190; Anthracene, 360 m p. 213 }	$C_{15}H_{19}N$, Heptacoline, 347 $C_{16}H_{21}N$, Octacoline, 362	$C_{13}H_9N$, Acridine, 360, m. p. 127	$C_{14}H_{10}O$, { Phenanthrol; Anthrol }	
						$C_{15}H_{12}$, Methylanthracene, m. p. 200–210 ($C_{16}H_{14}$, Dimethylanthracene, m. p. 224) $C_{15}H_{10}$, Fluoranthrene, m. p. 109				
Pitch.	C_nH_{2n+2}, Solid Paraffin					$C_{16}H_{12}$, Pseudophenanthrene, m. p. 150 $C_{16}H_{10}$, Pyrene, 371, m. p. 140–142 $C_{18}H_{18}$, Retene, 350, m. p. 99 $C_{18}H_{12}$, Chrysene, 440 (?), m. p. 249 $C_{22}H_{14}$, Picene, 510 (?), m. p. 338 $C_{24}H_{18}$, Benzerythrene, m. p 307	$C_{16}H_{11}N$, Chrysogene, m.p. 280–290 $C_{16}H_{11}N$, Imidophenyl-naphthyl, m. p. 330			

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THE LUMINIFEROUS ÆTHER.

BY PROFESSOR DE VOLSON WOOD.

I supposed that I had reported Herschel so faithfully that there was no occasion for criticism, and I now infer, from the statements of Prof. Chase in the last October number of this JOURNAL, that had I used "hypothesis" for "*assumption*," he would have been satisfied. I waive this point without discussion. The "questionable as to the correctness of the facts," that writer has misapplied. In the August number, he referred to "results which I supposed were new." As I had not confided that secret to any person, the correctness of the statement might be questioned. On page 300, he continues: "Prof. Wood says that 'in a pound of the æther there is 100,000,000,000 times the kinetic energy of a pound of air.' This discrepancy arises from his inadvertently omitting one cipher and making a rougher approximation than Herschel." This is an error. The "inadvertence" belongs to Prof. Chase. What I said was "in a pound of æther there is some 100,000,000,000," etc. I inserted the word "some" on purpose that I might agree approximately with those who should make a microscopic examination of the figures; knowing that in an off-hand statement of this kind, in a number of such magnitude, it was of little consequence whether the left hand figure were seven, eight, or even nine times as large. The word "some" inserted as it was, shows that it was only a rough approximation.

Then he proceeds to say: "Wood's result being 8×10^{11} nearly, while Herschel's is 811,801,000,000." I supposed that I must have given the result apparently attributed to myself, but I am unable to find it in my article; and I believe that it is a result of Prof. Chase's computation, and if so, why did he not make it agree with Herschel's. I do not, however, object to the value given, for I get 814,400,000,000, by using 186,300 miles as the velocity of light per second. Moreover, is not Herschel's result "8×10^{11} nearly?" But these hair-splittings belittle the subject.

For the benefit of those who are interested in the subject, but have not time to study it, I will give a very brief statement of the

manner in which the problem has been attacked. Herschel, on the hypothesis that the æther is as dense as air at sea-level, estimated the ratio of the elasticity to the density of the æther to be 17×10^{12} pounds per square inch. He made no estimate as to the actual density, nor actual tension, but gave it as his opinion that its tension was very great. Thomson, on the assumption that the mean displacement of a particle from its normal position was one-fiftieth of a wave length, found a corresponding density of the æther. Maxwell, in his article on "Ether" in the *Encyclopædia Britannica*, IX edition, on the hypothesis that the displacement was $\frac{1}{100}$ of a wave length, obtained his estimate of the density and elasticity. Other writers have obtained results on this principle.

Preston, on the hypothesis that the tension of æther exceeds the force necessary to separate the atoms of oxygen and hydrogen in a molecule of water, and that the probable inferior limit of this tension was 500 tons per square inch, computed its corresponding density.

In my solution no such arbitrary assumption or hypothesis was made. It was simply assumed that the æther conformed to gaseous laws, and the two constants—the solar constant and the velocity of light—were the data for making the equations numerically determinate in regard to the elasticity and density. This and other processes and results given in my article have not been attacked so far as I am aware.

Confirmation of Chemical Prediction.—Supposing the new element, Germanium (Gr) to be the Eka-silicium, predicted by Mendelejeff, to lie between silicon and tin, Lecoq de Boisbaudran (who, even prior to Mendelejeff, had surmised the existence of an element with atomic weight 72·28) now gets 72·27 by spectroscopic observation of a fragment too minute for other treatment. He assumes that the lines $\lambda = 412{\cdot}9$ and $\lambda = 389$ for Si, are homologous with the conspicuous lines 468·0, 422·6 for Gr, and with 563·0, 452·4 for Sn; and that the lines 395·2, 410·1, 430·6 for Al, Ga, In, are homologues; and he uses the atomic weights 28·0, x, 118·0 for the triplet Si, Gr, Sn, and the weights 27·5, 69·9; 113·5 for the triplet Al, Ga, In. Then for each triplet of wave-lengths, or of atomic weights, he finds the quotient, second difference ÷ leading first difference; and he determines x so that these quotients for atomic weights in the two series may be to each other as are the corresponding quotients for wave-lengths. He adds that by the same method he once predicted the weight of Ga within one-sixtieth of one per cent.—*Comptes Rendus, June 7, 1886.*

PHOTOGRAPHING WITH PHOSPHORESCENT SUBSTANCES.

At the stated meeting of the INSTITUTE, November 17th, Mr. Frederic Ives read a preliminary communication on this subject, giving the result of some investigations, which he had undertaken at the suggestion of Dr. Wahl.

After making a photograph of a street scene by exposing in the camera for thirty seconds, a tablet coated with Balmain paint and then placing it in contact with a photographic sensitive plate for about the same length of time, Mr. Ives made exposures on the lime-light spectrum, to determine to what kind of light the tablet was sensitive. He found that phosphorescence was produced only by exposure to the violet rays, and that the light given out by the excited tablet was chiefly the indigo-blue, to which photographic sensitive plates are more sensitive than to any other color. But he also observed that a tablet exposed to sunlight, and then given a rest of several hours in total darkness, in a cool place, became quite sensitive to the dark heat rays at the opposite end of the spectrum, which caused a temporary exaltation and corresponding rapid exhaustion of the feeble phosphorescence remaining in the tablet. He succeeded in obtaining strong photographic negatives showing this action, and concluded that by this means it would be possible to obtain camera photographs of perfectly dark objects which radiated or reflected sufficient heat, provided that the lenses used were capable of freely transmitting such dark heat rays.

M. Ch. Zenger, in a recent communication to the French Academy of Sciences, asserted that he had obtained a photograph of towers and other objects at midnight on a dark night, by the aid of a phosphorescent tablet, and attributed the result to the action of dark "actinic" radiations, which he supposed that the objects gave out at night. Mr. Ives pointed out that, as the tablet proved to be insensitive to such rays, Zenger's explanation was certainly incorrect. Mr. Ives's investigation had proved that bodies intensely heated by exposure to the sun during a hot summer day might, under certain conditions, be photographed at night by the action of heat which they radiated,—but the method did not seem sensitive enough to give such results with glass lenses, and he thinks

Zenger's photograph may have been due to unsuspected feeble phosphorescence remaining from a previous exposure in daylight, several hours or even a day or two before.

Mr. Ives offered explanations of other phenomena observed by M. Zenger, and concluded by claiming to be the first to discover that photographs of dark objects may be made in the camera, by the action of heat which they radiate or reflect.

BOOK NOTICES.

THE LUMINIFEROUS ÆTHER. By De Volson Wood, C. E., M. A. Van Nostrand's Science Series, No. 85. Price, $0.50. Reprinted from the *Philosophical Magazine*, with additions. New York. 1886.

In view of the importance which has been assumed by molecular hypotheses, in scientific investigation, the vague ideas which are still entertained respecting molecular æther—so vague as to have led to variations of more than a million-fold in estimates of æthereal density—are a reproach to science. This reproach, our author has, very commendably and very judiciously, endeavored to overcome, and, considering the number of novel questions he has had to meet, he has been very successful.

There have been too many printer's errors, and the very serious collateral misunderstandings, in which others had already given a wrong bias to popular interpretations, have already been noticed in the JOURNAL; but his proposal on pp. 9–11 is admirably and satisfactorily stated.

He asks, p. 10–11, "Can the kinetic theory, which is applicable to gases in which waves are propagated by a to-and-fro motion of the particles, be applicable to a medium in which the particles have a transverse movement, whether rectilinear, circular, elliptical, or irregular? In favor of such an application, it may be stated that the general formulæ of analysis by which wave-motion in general, and refraction, reflection, and polarization in particular, are discussed, are fundamentally the same; and in the establishment of the equations the only hypothesis in regard to the path of the particle is—it will move along the path of least resistance. The expression $V^2 \propto e \div \delta$ is generally true for all elastic media, regardless of the path of the individual molecules. Indeed, granting the molecular constitution of the æther, is it not probable that the kinetic theory applies more rigidly to it than to the most perfect of the known gases?"

This is the hypothesis of Herschel, the only one which has ever led to any numerical verification, or ever received any practical confirmations. It has given, correctly, the elasticity which the æther would have at the same density as the atmosphere, from which it is easy to find the elasticity for Thomson's or any other supposed density. If Prof. Wood will examine all the best density-estimates and give us one which is as accurate as Herschel's combined elasticity-density estimate, he will restore the credit which he helped, wrongly but unintentionally, to take from Herschel, and he will help remove all claim

to scientific value from two solutions which are based on the same data, and one of which is more than 1,600,000 times as great as the other.

On page 5, of his brochure, Prof. Wood says: "Beyond these facts, no progress can be made without an assumption." There is no assumption in saying that action and reaction must always be equal. The action of radiation from every point of the sun, produces a wave-velocity in the æther which is the same as that of light, and the rotary time-integral of the cyclical reactions of solar centripetal gravitation also produces a velocity, at every point, and for the whole cycle, equivalent to the velocity of light. The sum of the impulses communicated by the acceleration of solar-superficial gravitation during any cyclical rotation on its axis ($g t$), equals twice the average velocity which would be communicated if the efficiency of all the impulses were retained $\left(\frac{g t}{2}\right)$. The sum of the wave-disturbances of solar radiation during a solar rotation on its axis could have no more fitting representative reaction than the sum of the reactionary gravitating accelerations on the oscillating particles themselves.

If we represent the time of solar rotation by t, solar-superficial gravitating acceleration by g, and the velocity of light by v_λ, this perpetual equality of acceleration and re-acceleration may be represented by the equation $\frac{g t}{2} = v_\lambda$. By the law of conservation of angular momentum, $t \propto r^2$, while $g \propto \frac{1}{r^2}$, so that $g t$ is constant at all stages of nebular condensation, and the dependence of solar rotation, planetary revolution and luminous radiation upon a single energy at the centre of our solar system has been recorded in the heavens since the day of the great *fiat*, "Let there be light." P. E. C.

THE PREVENTION OF FIRE. CHIEFLY WITH REFERENCE TO HOSPITALS AND OTHER PUBLIC INSTITUTES. By William P. Gerhard, C. E. Published at 6 Astor Place, New York. Price, 60 cents.

This brochure groups well various good suggestions often previously reiterated by others. We like the author's earnest advocacy of "slow burning" construction in buildings, since no mode is absolutely fire-proof. He counsels the avoidance of vacant spaces, those between joists, in partitions and under stairways, to be filled with scoria or plaster of Paris, and outside covered with wire netting and plastered. He is not explicit as to floors, but we presume he means hardwood, such as oak; nor does he state, if it be adopted, how the extra weight of a scoria-filled roof is to be best supported. He advocates, most correctly, incombustible coverings for roofs, but we are surprised that he classes "tar and gravel roofs" among those which are very good. As to supporting heavy weight, we think he should have noticed the advantage of iron or wooden pillars (preferably the latter), *sheathed thickly in cement.* What he states about hidden dangers in flues and other flimsy kind of construction is very true, and good attention is given to proper heating, illumination, laundry fixtures, water and appliances for fire extinguishment. If the warnings of this pamphlet were well heeded, the number of fires would undoubtedly be largely diminished. N.

Unerh. Jahrgang No. 20, of the "Berichte der d. chem. Gesellschaft," has just been received from R. Friedländer & Sohn. Berlin.

This is the most interesting number for a long time, and was doubtless edited with especial reference to the late meeting of the Physicians and Naturalists in Germany's capital. Its 51 pages (S. 3517–S. 3568, inclusive) are full of the varied notes and Abhandlungen, which have given its very definite character to this publication. The many-sided nature of its contents may be gathered from the following titles: "Die Bedeutung der Alcohol-Entziehung," "Ueber den kritischen Druck," "Die Synthese des Cognacs," "Versuch einer chemischen Theorie des Lichtes," "Vereinfachung eines der meist gebrauchten Laboratoriumsgeräthe," "Ueber den Zusammenhang zwischen Constitution und Krystallform," "Ueber einen einfachen Thermo-regulator," "Vorlesungsversuch" (an ingenious method of showing to a class the blue color of water), "Eine neue physikalische Constante und ihre Verwendung zu Moleculargewichtsbestimmungen," "Zur chemischen Nomenclatur," "Zur Constitution des Benzols" (this article includes an entirely original graphic representation of the benzol hexagonal molecule); a sharp retort to H. C. Bissig's supposed correction of a melting point; a joint article (A. Riese and P. Böhm) on "The Isolation of one of the Sulpho-chlor. Benzol Compounds," "Ueber die Drehkraft in der Natur," etc., "Zur Kenntniss der Zuckersäuren." Among the referate we may single out the discovery of a new metal, to which the name "Pankowium" has been given. It is thought by the discoverer, Herr Heuschrecker, that two other new elements to which he gives the names "Gesundbrunnium," and "Viehhofium," are associated with the first in small quantity." "A New Air-Pump," "Reasons for Belief in the Hour-Glass Form of certain Molecules."

Under organic chemistry are "The Condensation Products of Aldehyde," "Stanislausine," the odoriferous constituent of *Cimex lectularius*, by E. Stanislaus, and a supplementary paper by B. Neinmeyer on "The Difficulty if not Impossibility of Purifying the Body of Stanislaus," on "Thiophenomenaldehyde," the foulest smelling substance of modern organic chemistry. Items in physiological and analytical chemistry follow. Under the head of "Patents" is one of a new black dye, said to have been taken out by a Philadelphian. It consists of "gefälltes Palladiumiodid, Gastheer, Blauholzextract, Russ, Anilinschwarz, Tinte und Schuhwichse," which being mixed in the proportion of their molecular weights, are kept twelve hours at a temperature of 385°. An English patented sparkling wine, called Xylomousseux, is made by distilling shavings and potato skins, saturated with molasses, and charging with carbonic acid at high pressure. The remaining pages of the number are devoted to chemico-literary articles in honor, no doubt, of the distinguished foreign visitors of the great scientific gathering.

A Manual of Lithology. By Edward H. Williams, Jr., E. M., Professor of Mining Engineering and Geology, Lehigh University, South Bethlehem, Pa.

This little book of 135 pages, 5¾ x 3¾ inches, only proposes "to combine

a thorough knowledge of the elementary portion of the subject with a brief account of the principal rocks and a ready method for their determination." To do this, it combines, to a large extent, the definitions as given in Lawrence's *Cotta* ("Rocks Classified and Described"), with the tabular method of mineral description in Frazer's *Weisbach* ("Tables for the Determination of Minerals"), except that here the columns and the descriptions are independent. The little work is divided into a first part, consisting of a chapter on "Lithology," and one on "Mineralogy;" a second part, with a chapter on "Definitions," etc.; another on "Primary Rocks," considered as acid vitreous, basic vitreous, acid crystalline, intermediate crystalline and basic crystalline; a third chapter on "Sedimentary Rocks" of (1) the sedimentary and (2) the fragmental class; a fourth chapter on the "Metamorphic Schists," to wit: the acid series (feldspar and quartz group), and the basic series, (1) (chlorite, talc and hornblende group), and (2) argillaceous group; a fifth chapter, including the serpentine, garnet, olivine, coal, guano, iron and mineral groups. Part III contains a scheme for determining rocks and a classification. This latter is a courageous attempt to put into six pages enough definitions to enable the learner to classify and determine a rock.

The little book is well printed and proof-read, though the paper is a trifle thin. In some cases, the words of Lawrence's *Cotta* are slightly altered or transposed, as in the definition of texture, p. 2; syenite, p. 63, when "pyroxene" is introduced, an association that would have made Von Cotta frown, etc., etc., and in some cases, the author has bodily transposed the defining phrases from one thing to another, as in his enumeration of the kinds of structure which are taken from Lawrence's varieties of "Texture," even to the "Spherulitic or *Globuliferous*," which Lawrence has left as a little monument of kakophony to himself.

In some few places, carelessness appears, as in his note on page 2, where he applies the term "magma" to the homogenous or amorphous matrix of crystals, which is exclusively employed for a precipitate or mass of crystals, or mixture of substances in a pulpy or pasty state. (See Watts' *Dictionary of Chemistry*.)

But independently of a few blemishes of this kind, the little pocket companion will be of use to practical miners and beginners in rock study, in spite of the fact that it leaves out of account all that the modern Zirkels and Rosenbusches have done. It were to be wished, though, on this account, that if the order of sequence in Von Cotta was to be abandoned, some of the modern systems had been adopted. Lossen's would have been a good one for the eruptive rocks, because it has been adopted by the International Geological Congress.

P. F.

ARC AND GLOW LAMPS. A PRACTICAL HAND-BOOK ON ELECTRIC LIGHTING. By Julius Maier, Ph. D., Associate of the Society of Telegraph Engineers and electricians. New York: D. Van Nostrand.

This volume, as one of the excellent "Specialist's Series," is to be commended for its faithfulness to the technical topics treated. It is divided into

four parts, the first of which contains descriptions of methods and instruments used in practical measurements and also quotes results of some of the recent measurements for determining the light-efficiency of dynamos. The arrangement of leads and the special devices for regulation both in arc and glow lamp installations, and the cost of electrical illumination are also here discussed.

Part second treats of arc lamps, their construction and efficiency. All the well-known and some little-known lamps are figured and discussed in their mechanical and electrical details. In treating of the light-efficiency of the various arc lamps, the author gives the results of the tests made in Paris, Vienna and Philadelphia. The latter tests made under the direction of Professor Wm. A. Anthony, Chairman of the Section on Arc Lamps of the Board of Examiners of the FRANKLIN INSTITUTE, are referred to *in extenso*, and the tabular results reproduced. Part third is devoted to the construction and efficiency of glow lamps. It is a compend of the experimental tests made on incandescence lamps. Of especial interest are the references to the experiments of Siemens and Halske on unimproved and improved filaments and to the much mooted relations between efficiency and life in these lamps. The concluding part reviews the application of electric lighting to light-houses, ships, collieries, military operations, railway trains, theatres, photography, the microscope and surgical operations. M. B. S.

TOWN GEOLOGY: THE LESSON OF THE PHILADELPHIA ROCKS. By Angelo Heilprin, Professor of Invertebrate Palæontology at, and Curator in Charge of, the Academy of Natural Sciences, Philadelphia.

This book is a handsomely printed and edited, large margin octavo of 134 pages of very readable reading-matter, adorned with very pleasant sketches in the text and fine plates.

Prof. Heilprin adopts that happy style of presenting the scientific facts with which he is familiar, which Hugh Miller and Huxley and Tyndall, and many others have done much to associate both with sound and with unsound science. His points of view are original and striking, as is the manner of his introducing the subject in hand. After thirty-two pages of general observations, he takes up the rocks of the Schuylkill and Wissahickon, and follows this by a chapter on the oldest patch of land. It is highly to the credit of Prof. Heilprin that while he tells us much that is interesting, he avoids committing himself to any one of the numerous hypotheses in regard to the age of these rocks, which one and all are as yet in unstable forms. It would have been most natural to do this, and it must have been difficult to avoid it, which only shows that the more credit is due to Prof. Heilprin for his skill and tact. We venture to say that the average reader, beguiled from one page to another by the agreeable and profitable lines, will not note the absence of this dogmatizing. The same judicial impartiality is observable in the maps at the end of the book, where the rocks in dispute are modestly called Philadelphia schists and gneisses, a characterization in which all can agree. The plates are well engraved, and the book is creditable to author and printer.

P. F.

THEORY OF MAGNETIC MEASUREMENTS. WITH AN APPENDIX ON THE METHOD OF LEAST SQUARES. By Francis E. Nipher, A. M., Professor of Physics in Washington University; President of the St. Louis Academy of Sciences. New York: D. Van Nostrand. 1886.

This little volume of scarcely 100 pages octavo, is an excellent *résumé* of the theory necessary to practical determination of the three magnetic elements—declination, dip and intensity. As is well known, Professor Nipher some years ago made a comprehensive magnetic survey of his own state—Missouri—in such a manner as to do credit to his interest in this department of science. The experience thus gained, and the knowledge of details of methods and instruments, having been frequently requested from the Professor, he has very properly made reply in the form of the present little book, so as "to furnish information relating to the practical details of a magnetic survey."

In order to be able to present an explanation of proper methods of reduction of the observations, the author also finds it convenient to give a brief appendix on the method of least squares. The volume is characterized by accuracy and thoroughness, and cannot fail to be of service to those who wish to become acquainted with good method in this important field. Practical examples are worked out according to the mathematical theory developed, and, very appropriately, all is presided over by a fine frontispiece of Carl Friedrich Gauss, to whose genius the science of terrestrial magnetism chiefly owes its existence. M. B. S.

COMETARY SPECTRUM.—Trépied, at Algiers, April 7th, gets a continuous spectrum for the Fabry comet, together with three bright hydro-carbon bands that are strongest in the spectra of coma and tail, though the nucleus is very brilliant and star-like. The same thing is observed by MM. Thollon and Perrotin, at Nice. Thus, as with Encke's comet last year, the light from luminous gases predominated.—*Comptes Rendus, May 3, 1886.*

LIQUID O AND N.—Wroblensky finds for the density of liquid oxygen, 0·6 at —118° C., the critical temperature; 1·24 at —200°; and $1·212 + ·00428\ T - ·0000529\ T^2$ for intermediate temperatures, T being the absolute temperature. This gives the atomic volume less than fourteen, not sixteen, as Dumas thought. For nitrogen, Wroblensky gets the densities ·4552, ·5842, ·83, ·866 at the respective temperatures —146°·6, —153°·7, —193°, —202°, the freezing-point being —203°. Thus, the atomic volume is nearly 15·5.. Air, at these low temperatures and pressures, behaves like a mixture of unequally-volatile liquids: its composition varies with temperature and pressure, and its density conforms to the theory for mixtures. As Wroblensky employed only slight or moderate pressures, Amagat, who last year got for oxygen a density above 1·25 by 4,000 atmospheres' pressure at 17° C., suggests that cold and pressure combined may so far increase the above densities that, while the atomic volumes of S, Se, Te may be equal, that of O may be just half as great.—*Comptes Rendus, May 17, 1886.*

Franklin Institute.

[*Proceedings of the Stated Meeting, held Wednesday, November 17, 1886.*]

HALL OF THE INSTITUTE, November 17, 1886.

Vice-President CHAS. BULLOCK, in the Chair.

Present, 109 members and eleven visitors.

Additions to membership since the previous meeting, eight.

By direction of the Chairman of the Committee on Science and the Arts, the Secretary reported the Committee's recommendation for the award of the *Elliot Cresson Medal* to ROBERT H. RAMSEY, of Philadelphia, for his "Car-Transfer System and Apparatus;" and to THADDEUS S. C. LOWE, of Norristown, Pa., for his "Improvements in the Manufacture and Applications of Water-Gas for Heating and Lighting."

The recommendations were severally approved, and the Secretary was directed to take the usual measures to carry them into effect.

A report of progress was presented on behalf of the Special Committees having in charge (1.) the preparation of a plan for a "State Weather Service," and (2.) the consideration of Mr. Paul La Cour's protest against the award of the *Elliot Cresson Medal* to PATRICK B. DELANY.

MR. FRED'K E. IVES, of Philadelphia, presented a preliminary communication on the "Application of Phosphorescent Substances to Photography." An abstract of this communication appears in this impression of the JOURNAL.

The Secretary's report embraced remarks on the "Future Water-Supply of Philadelphia," on the "Progress of the East-Side Connecting Railway," and on some of the "Indirect Advantages of Natural Gas."

Adjourned. WM. H. WAHL, *Secretary.*

DRUIDICAL REMAINS IN PERU.—M. Daubrée offers, in the name of M. Habich, Director of the School of Civil Constructions and Mines, of Lima, the fifth volume of *Anales de Construcciones Civiles y de Minas.* An article by M. Chalon, on "The Buildings of Ancient Peru," is worthy of notice and of universal interest. To the primitive epoch, succeeding the pre-historic, belong constructions laid with rough blocks, sometimes of very great dimension. It is very remarkable that these monuments offer the greatest resemblance to those which are known in the old world, particularly in France, under the names of raised stones, menhirs, cromlechs, dolmens and the general term druidical. They are very numerous and are spread through all parts of the territory of Peru. According to the author, they appear to have a religious significance and to have served for sepulchre and sacrifice.—*Comptes Rendus, May 24, 1886.*

The "NOVELTIES" EXHIBITION of the FRANKLIN INSTITUTE, 1885.

ABSTRACTS of REPORTS of the JUDGES.

(*Continued from page 400.*)

GROUP 12*a*.—GAS MANUFACTURE FOR ILLUMINATING AND HEATING, AND APPARATUS THEREFOR, INCLUDING COAL- AND OIL-GAS AND NATURAL-GAS APPLIANCES.

Judges:—Griffith M. Eldridge, Wm. H. Greene, L. B. Hall, Wm. D. Marks, G. M. Ward, Moses G. Wilder, Wm. H. Wahl, *Chm.*

The exhibits referred for examination embraced the following:

(1.) Exhibit of The Lowe Manufacturing Co., of Norristown, Pa.—a comprehensive exposition of the manufacture and applications of Water-Gas.

(2.) Exhibit of the Pennsylvania Globe Gas Light Company, of Philadelphia.—The Royal Gas Machine.

(3.) Exhibit of Rand & Harmer, of Philadelphia.—The Victor Gas Machine; and

(4.) Exhibit of Jas. P. Wood & Co., of Philadelphia.—The Globe Gas Generator.

Air-Carburetting Machines.—These machines operate on the principle of saturating atmospheric air with the vapors of the lighter products of petroleum; the vapor-laden air, possessing high illuminating qualities, passes to the burners through distributing pipes, after the manner of utilizing coal-gas.

There are two types of these machines, both of which are represented at the Exhibition.

In one, the air is forced by mechanical means, to pass over a body of gasolene, and to charge itself with the illuminating vapors at the ordinary temperature. This class comprises the so-called air-blowing machines.

In the other, artificial heat is employed to effect the vaporization of the gasolene. This class comprises the so-called caloric machines.

The machines exhibited by *Rand & Harmer* and the Pennsylvania Globe Gas Light Company, belong to the first-class; that exhibited by Jas P. Wood & Co., belongs to the last.

RAND & HARMER, PHILADELPHIA.

The Victor Gas Machine.—This machine has an air-pump, consisting of a meter-wheel, which is actuated either by weights and pulleys, or (in the specimen examined by the undersigned) by an overshot water-wheel. When the machine is in operation, the pump delivers an automatically-controlled current of air through an air pipe to a carburetter, in which an extended evaporating surface of gasolene is presented to it. The air is thus "carburetted," and in this condition passes to the burners.

The air-pump and carburetter are made of copper and brass, except the frame, which is of iron. The carburetter is made of sufficient capacity to hold a six-months' or year's supply of gasolene.

In the machine exhibited, the controlling mechanism by which the quantity of gas made is automatically regulated by the amount being consumed, consists of a floating air-chamber—on the principle of a gas-holder—and which is placed on top of the air-pump. A lever is attached, at one end, to a vertical stem rising from the floating air-chamber, and at the other, to a stop-cock in the supply-pipe, which furnishes the overshot wheel, above-named, with water. When the gas consumption increases the air-chamber descends, the water-supply stop-cock is opened wider, a correspondingly larger quantity of water is delivered in the buckets, the water-wheel and meter-wheel on the same shaft are caused to revolve more rapidly, and the result will be the delivery of a correspondingly larger quantity of air to the carburetter and of carburetted air to the burners. The reverse action takes place when the consumption of gas is reduced, and, when the lights are all shut off, the stop-cock is entirely closed, and the machine comes to rest.

The makers state that the carburetter containing the gasolene is placed in the ground, at any required distance from the building to be lighted, and that they provide it with a safety-valve, as a safeguard against undue pressure either way.

They claim for it, simplicity of design; entire independence of atmospheric changes, in respect to the quantity and quality of the gas; and (where the water-wheel is used) entirely automatic action.

The machine exhibited was tested by the judges to its full capacity of forty lights, as rated by the exhibitors, and was found to be

equal to this duty. The following test was made to determine the promptness with which the machine would adjust itself to extremes of consumption.

Provision was made by which all the lights, or a number of them, could be extinguished simultaneously, leaving only one, or a predetermined number, burning. The experiment gave the following results:

	Observed Pressure.
With 5 lights on, ...	1·5 inches.
With 38 lights on (lighted as quickly as possible), . .	·6 inch.
With 1 light on (20 suddenly put out, and 17 as quickly as possible), ...	1·8 inches.
Total variation of pressure from (approximate) maximum to minimum capacity of machine, ...	1·2 inches.

The single remaining light exhibited considerable blowing, persisting for several minutes, but was not blown out.

Photometric examination of the gas delivered by the Victor machine gave the following result, as the mean of twenty observations.

FIRST SERIES.

Gas consumption per hour, ...	5 cubic feet.
Ignition pressure, ...	1 inch.
Burner used, the U. S. Standard.	
Illuminating value, ...	22·33 candles.

SECOND SERIES.

Gas consumption, ...	5 cubic feet.
Ignition pressure, ...	1·5 inches.
Burner used, Gefrorer's (furnished by R. & H.)	
Illuminating value, ...	19·5 candles.

(*Observers: Wahl and Ward.*)

The judges admit the claims of the makers so far as they relate to the simplicity of design and automatic action of the "Victor" machine, but cannot admit the claim that the quality and quantity of gas made will be entirely independent of atmospheric changes.

With the carburetting-chamber buried in the ground at a distance from the house to be lighted, and provided with a safety-valve to make it secure against back-pressure, the machine would appear to meet the requirements on the score of safety which the insurance interest demands.

The regulating mechanism, *i. e.*, the floating air-chamber with

automatic water-supply is ingenious, and where so situated as to be free from liability to freezing, may be commended as a simple and useful device.

THE PENNSYLVANIA GLOBE GAS LIGHT COMPANY, PHILADELPHIA.

The Royal Gas Machine.—This machine comprises an air-pump, which is the usual device of a meter-wheel actuated by weights and pulleys; a carburetter, in which the air is made to pass over fibrous material saturated with gasolene, and from which it passes to the burners.

To meet the objection urged against the usual form of carburetters, in which the entire supply of gasolene is placed, viz., that the more volatile portions will first pass off, leaving the less volatile portions behind, thus yielding a variable light, at first very rich and becoming gradually impoverished—the makers have devised what they term an automatic feed, the object of which is to feed gasolene to the carburetter from a storage tank, in exact proportion to the consumption of gas. This device consists substantially of a box situated conveniently with reference to the storage tank and carburetter, and provided with a "float"-valve, by which the quantity of gasolene passing into the latter is automatically regulated by the consumption of gas at the burners. In other respects, the machine resembles those in common use.

The machine exhibited was tested by the judges to its full capacity (twenty-five lights) as rated, and was found to be equal to this duty.

The makers claim "simplicity of construction and operation, durability, safety and general utility."

To test the promptness of regulation of this machine under sudden and extreme variations of consumption, and the photometric value of the gas, the judges submitted it to the same tests as described in the case of the "Victor," and with the following results:

	Observed Pressure.
With 25 lights on	1·5 inches.
With 1 light on (24 quickly put out), ...	1·8 inches.
Total variation of pressure from maximum to minimum capacity of machine, ...	·3 inch.

The single remaining light flared slightly, but in a few minutes became steady.

PHOTOMETRIC RECORD.

Results in the mean of 20 observations:

Ignition pressure, ...	1 inch.
Consumption, ...	5 cubic feet.
Burner (*Standard*).	
Illuminating value, :	19·65 candles.

The makers state that they place the carburetter (and storage-tank) and feed-box, six or more feet underground, and at least fifty feet from the building to be lighted.

The judges are favorably impressed with the regulating qualities of the machine, and with the general excellence of its workmanship. They regard the automatic feed, which is the only novelty which is claimed for it, as a meritorious feature and worthy of commendation, since, in their judgment, it will permit of the production of gas of more uniform quality and will act as a safety-valve against the accident of excessive back-pressure. Substantially similar devices, however, for accomplishing the same objects are and have been long in use. The only objection that has been found against them, is the liabilty of flooding the carburetter in the event of the valve from any cause becoming inoperative.

The use of a wire-gauze strainer over the inlet orifice, to prevent the entrance of any obstructing material from the storage-tank—which is adopted by this company—the judges regard as a reasonable precaution against accident from this cause.

JAS. P. WOOD & CO., PHILADELPHIA.

The Globe Gas Generator.—This is a so-called "caloric" machine (*i. e.*, one in which the gasolene is vaporized with the aid of heat) as distinguished from the so-called "air-blowing" machine previously described. It is operated by steam, where this is available, or, by a system of hot-water circulation, the heat being supplied by means of gas taken from the machine itself.

It comprises a storage-tank for the gasolene; a -shaped pipe communicating therewith, one leg of which containing liquid gasolene, furnishes a constant hydrostatic column of sufficient pressure for the continuous action of the machine, while the other leg contains a vapor column of the same pressure; a gas-holder communicating with the vapor column and provided with suitable valves for automatically admitting gasolene vapor and air in predetermined proportions, and in quantity regulated by the consump-

tion; and a system of steam or hot-water circulation for effecting the artificial vaporization of the gasolene.

The machine embodies a number of novel features, of which the following are noteworthy:

A method of securing an operating force for the machine without the use of a pump, and without elevating the storage-tank above the level of the machine. This is accomplished by placing the storage-tank (containing the gasolene) below the level of the machine, and running a pipe from the bottom of this tank, downward about nine feet, then turning it upward, surrounding this part with a heating-jacket, and attaching the upper extremity to an injecting mechanism connected with the gas-holder. This construction provides a hydrostatic column (of approximately three-pounds pressure) of gasolene, which, being in communication with a vapor column in the other leg of the bent pipe, gives to this a constant pressure, and supplies the force for actuating the machine.

A pipe leads from the top of the storage-tank to the lowest point of the gas-main, for the purpose of giving constant automatic drainage, and of establishing and maintaining equilibrium between the gasometer and the tank.

The pressure of the vapor column is utilized for regulating the heat required for vaporizing the gasolene. This is effected by a valve in the gas supply-pipe leading to the heating-burner, which is opened and closed by the tension of the vapor.

A system of heating and circulating water below the source of heat by placing one branch of the circulating-pipe within the other, thus keeping outflowing and return currents separated, and the adjustment of the operating mechanism in such a manner that the vapor-valve shall be fully opened and closed where the consumption is limited to a few burners, and partly opened and regulated where many burners are in use.

The actuating mechanism consists of two valves—a vapor valve, moving vertically, and an air-valve, which can be adjusted to deliver any desired proportion of air with the gasolene vapor entering the holder.

The operation of the machine is briefly as follows:

The gasolene vapor is generated (when the machine is in action) in the jacketed pipe before described, and forced through a vapor-valve into what may be called an injector, placed near the bottom

of the gas-holder and communicating therewith. This vapor-valve is opened automatically by the descent of the gasometer to a certain point, through the action of a trip movement connected therewith by a pivoted lever; when the gasometer rises again to a certain point the vapor-valve is closed. Connected with this injector is an air-valve, which admits air by inspiration as the vapor is injected, the proportions of the mixture being regulated by means of an adjustable screw-weight.

The heating apparatus is a coil of pipe, with leading and return branches above described, the heat being supplied by gas furnished from the machine, and automatically regulated by the tension of the vapor.

In practice, the makers explain that they place their machine in a small enclosure in the open air, and the heater near this enclosure, with an open-air space between them, to prevent dangerous accumulation of gas by leakage, should any occur.

They claim for this machine, as compared with other "caloric" machines, simplicity, in dispensing with the pumping of air, water or gasolene; doing away with the necessity of elevating either water or gasolene to secure an initial actuating pressure; positive safety against flooding the machine with gasolene should the heat be accidentally stopped; and doing away with the necessity of handling and providing for the removal of condensed gasolene after it is once placed in the tank.

They claim, as compared with the "air-blowing" machines: The maintenance of a positively uniform quality of gas under all circumstances, the proportions of air and vapor delivered remaining constant, no matter to what extent the amount of gas produced may vary.

The machine was submitted to the same tests as the others, before described, to determine its regulating qualities, and with the following result: The machine was rated as a 100-light machine, and was found to be capable of performing that duty.

	Observed Pressure.
With 30 lights on, ...	0·9 inch.
" 50 " " (loss not appreciable.)	
" 75 " "	0·7 "
" 100 " "	0·65 "
Turning off 50 lights suddenly, ...	0·9 "

A single gas-jet left burning exhibited little or no blowing.

PHOTOMETRIC TESTS.

Gas consumption per hour, ...	5 cubic feet.
Ignition pressure.	1 inch.
Burner used (*U. S. Standard*).	
Illuminating value, ...	23·83 candles.

The judges believe that the claims of the makers above enumerated are substantially correct. The mechanical details are very ingeniously contrived, and the features on which the automatic action of the machine depends appear to be effectual and reliable. The avoidance of the use of an elevated storage-tank, and of mechanical means of securing an initial actuating pressure, and the method adopted for securing and maintaining such pressure, are ingenious and commendable, inasmuch as they render the accidental flooding of the machine, with gasolene, impossible. The compactness of the machine also is noteworthy.

NOTE.—The photometric observations in the foregoing were made on a 100-inch Bunsen photometer, having a candle balance and decimal meter at the appropriate ends. A sperm-candle burning two grains of hydro-carbon a minute was used as the standard of comparison. The mode of procedure consisted in (1), determining the quantity of gas consumed in one hour; (2), the water-pressure at the meter and at point of ignition; (3), to determine the consumption of the candle. Five-minute duration tests were made to enable the observer to take ten photometric observations, and also to determine the consumption of the candle. The mean of the ten observations, corrected by the proper reduction factor when it was needed, was taken as the correct result. From this result could be obtained the candle-power per cubic foot of gas burned.

(*To be continued.*)

SLIGHT VARIABILITY IN VELOCITY OF LIGHT.—Cornu calls attention to the confirmation which Michelson and Morley's recent measurement of the velocity of light along a swift current of air or water gives to Fizeau's result of 1851. The air-current does not sensibly affect the velocity of light; the water-current affects it by about half of the velocity of the stream. This agrees with Fresnel's surmise, based on an observation of Arago, that the absolute velocity of light is altered by $\frac{n^2-1}{n^2}$ of the current's velocity, n being the index of refraction; and it may indicate that the ether does not even partially partake of the current's flow.—*Comptes Rendus, May 31, 1886.*